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APEX: A GAMING SIMULATION FOR AIR POLLUTION EXPERIENCE IN A SIMULATED METROPOLITAN ENVIRONMENT. APEX REPORT NUMBER 1. CONCEPTUAL DESIGN

University of Southern California
Los Angeles, California

December 1968

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UNIVERSITY OF SOUTHERN CALIFORNIA

APEX: A GAMING SIMULATION FOR AIR POLLUTION EXPERIENCE IN A SIMULATED METROPOLITAN ENVIRONMENT

APEX REPORT NO. 1 - CONCEPTUAL DESIGN

December, 1968

Comex-Air Pollution Computer Research Project
School of Public Administration
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Los Angeles, California

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INTRODUCTION

Growing concerned with a complex set of problems of metropolitan areas, various agencies have been searching for better ways to train professionals to meet the dynamic situations they will face as they struggle with those problems. For such professionals must not only be provided with the means for acquiring knowledge and skills about their own particular specialties, whether traffic or schools or air pollution, they must also be given opportunities to become aware of the complex interpendencies among the whole set of metropolitan problems and issues. Recognizing the need for creating new programs which will provide this broader problem context, the Air Pollution Control Institute was established with the specific intent of training future air pollution professionals in a context which would deal more adequately with these critical interdependencies between air quality and the complex natural and social environment of the metropolitan area.

This report describes the initial steps which have been made in the development of a special gaming-simulation to meet this need for the Air Pollution Control Institute and its training program. Here the initial set of concepts are described as it is intended that they be developed for this gaming-simulation, as a combination of a carefully developed simulated metropolitan environment in which trainees can become aware of the key decision roles in the private and public sectors of the metropolitan political economy and around which a variety of more detailed decision exercises can be built.

This report describes the kinds of computer operations and decision or role activities which seem most desirable for these training purposes.

They have been developed within the limits of a practical, workable gaming simulation. These proposals strike a reasonable balance between complexity or "richness" of environment and workability of the completed gaming simulation. In the process of development, initial consideration has been given to as many as possible of the problems that can be expected in further stages of development. Yet past experience indicates that all such difficulties cannot now be foreseen. Thus, it should be expected that it will be impossible to accomplish everything that is reported here. In this sense, this is a report of ideal intentions rather than a proposal for what achievements can be expected with one hundred percent success. (At the same time, of course, it will probably prove possible to accomplish many refinements which have not been proposed.) In other words, what is proposed here is what is currently conceived to be the most desirable gaming simulation of a metropolitan environment for air pollution control training purposes which can be accomplished within the constraints of effort and time available.

This report outlines as rich and complex a gaming simulation as can be expected in terms of the current state of the art. It is intended that the emphasis be placed on the larger context within which air pollution problems occur so that the operations of air pollution control agencies take place with a realistic perspective. Thus, air pollution will be seen as one in a set of problems of metropolitan areas. And the air pollution control agency and officer will be seen as one in a set of roles dealing with metropolitan problems and issues. Within this context, this gaming simulation is intended to provide a training framework within which professional trainees can be helped to understand the problems of other decision roles, the interdependencies of air pollution with other problems and issues, and the ever-present possibilities of alternatives in dealing with complex sets of problems or with air pollution.

The format and style of this gaming simulation is based on a simulated metropolitan social-political-economic-natural environment which raises both routine and irregular problems which must be dealt with by trainees functioning in key gamed decision roles. Gamed decisions will have impact on the simulated environment, on the other decision roles, and also on the person who has made the initial decision. Decisions will have both long and short run impacts. And additional problems may be raised by interactions between particular decision roles, as they must compete for scarce natural and fiscal resources, as well as for the scarce time of other decision makers.

In this report the general use of gaming simulations will be described briefly, including the initial but growing set of prototypes developed for urban and metropolitan purposes. This will then be keyed into the developing program of the Air Pollution Control Institute, with special emphasis on the ways in which this gaming simulation might be used to aid in training air pollution control officers.

The bulk of the report will be devoted to a more detailed description of intended development of the simulated metropolitan environment, the gamed decision roles, the gamed problems and issues, interactions among roles and with computer simulations, student preparation and support materials, the proposed data system, and future development stages required to complete this gaming simulation so that it can be made an integral part of the air pollution control training program.

GAMING-SIMULATION FOR AIR POLLUTION CONTROL TRAINING

Gaming simulations have been developed primarily to deal with situations which are virtually impossible to simulate in any way except as an operational setting in which actual human decision makers handle much of the coordination and integration of complexity. Thus, these gaming simulations usually have been developed to deal with very dynamic, complex situations which cannot readily be modeled in straightforward mathematical formulations, or which cannot, in their entirety, be converted to computer programs. Any very complex and rapidly-changing situation has critical relations that cannot be so formulated that the outcomes become predictable.

When such dynamic, complex situations are the basic framework within which professionals must operate, and when some grasp of the complexities, interdependencies, and uncertainties is critical, then an understanding can be acquired by many years of actual professional experience. For a growing number of professions, the urban and metropolitan areas of our country are the dynamic and complex situations in which they must learn to operate. An air pollution control professional, like many other professionals, finds himself in such an environment, where it is equally important that he acquire some understanding and skill in social-political-economic realities as that he learn how to deal with the complexities of the air, industrial processes, chemistry and biology.

Gaming simulations are hybrid simulations, combining a computer simulation of those relationships and processes which can be expressed in mathematical or computer language with gamed decision exercises for those relationships and processes which cannot be so expressed. Only in this way can something approaching the full complexity of the metropolitan area be built as a framework for understanding the knowledge and skills required for a particular professional role. Only in this way is it currently possible to build workable models of the reality of urban areas - models that are partly expressed as computer programs and partly expressed as gamed decision exercises keyed into the computer simulation. Such exercises seem to be the main current possibility for dealing with the important complexities of human interaction, including conflict and cooperation about goals, resources, and benefits. The essential human social activities of bargaining, compromise, and competition can only be dealt with reasonably adequately by permitting people to place themselves in the roles of key decision makers, make decisions under real pressures, then live with the results of those decisions in a simulated future.

Students face an exceedingly difficult task when they are expected to grasp such major complexities through the normal types of classes, seminars, and problems. Case studies and special problem environments can add much, but they seldom deal with more than a small portion of the total complexity, and they usually do not provide the dynamics of change over time, with the student being affected by the environment as well as his decisions having impact on that environment.

In the long run, various life experiences will enable them to develop their abilities to understand and deal with such complexities and dynamics. They will increasingly become aware of the limitations of piecemeal approaches to interdependent problems. They will come to understand something about the more indirect affects of their decisions, as well as those reaching farther into the future. If they are lucky, they will have enough satisfying and successful experiences to make their growing awareness of complexity and interdependence useful, but they may also find it so frustrating that they retreat into a narrow professionalism, concentrating on the merely technical aspects of their problems.

Gaming simulation has the potential for helping student professionals take a worthwhile first step toward an awareness and understanding of complex and dynamic situations. Such an initial start promises to lead toward a more rapid achievement of competence to deal with professional problems in such situations. In gaming simulations it is possible to reduce the time span of simulated reality markedly, so that significant experiences which might take years can be experienced in months, weeks or days. Such gaming simulations promise the possibility of insuring that students have exposure to certain critical experiences which they might never face in the real world, or at least not for many years into their professional careers.

Gaming simulations provide the possibility of giving students an opportunity to "play" other decision roles besides the one they are training for, so that they can get some ideas, some feeling, for the situation as seen from a variety of perspectives. And this is especially important when the other roles are those with which he will be interacting as a professional in the real world. Gaming simulations also offer the opportunity, not yet really tested, for "reliving" various critical experiences -- the opportunity, seldom found in real life, of starting back at the point of some key decision or interaction and seeing what might happen if some other path had been followed.

Above all, the gaming part of gaming simulation offers the possibility of viewing metropolitan phenomena in terms that are more humanly-meaningful than simulations which are entirely simulated by mathematical models or computer programs. Thus, "man is the measure" of whether computer output, reporting information about the simulated metropolitan environment, is meaningful to man. Human beings playing the decision roles also provide measures of whether or not men can understand dynamics and complexities from the perspectives assumed in the way those roles are structured. And people who actually operate in the key decision roles in the real world can provide a measure of whether the gamed decision roles provide a sufficient semblance of reality to make useful training experiences. (Of course, such gamed decision roles cannot mirror reality completely. They are necessarily abstracted and simplified from the dynamics and complexities of the real world. But there are many ways to abstract and simplify, and knowledgeable and experienced professionals must provide the major evaluation of the adequacy of such gaming simulations.)

Gaming simulations have been developed for a considerable range of such complex situations, and the variety is rapidly increasing. Most familiar are the war games, business management games, and various kinds of simulated training exercises (flying, driving, navigation, and so on). But now games have been developed for hospital administration, election processes, international relations, and many others.

But of most interest here are some of the prototype urban and metropolitan gaming simulations. These include the Community Land Use Game (CLUG) Metropolis, CITY, METRO, and several others. CLUG is a "board game" in which the major private economic relationships of a city are simulated through a set of game rules, while players act as entrepreneurs who buy and develop land and buildings; build and operate industries, stores, and housing; and join together to provide streets, sewers and other utilities required for development. Thus, CLUG contains the essential of urban economics in very simplified form, including the locational influences of transportation costs. Metropolis places more emphasis on the political and public sector relationships, since it focuses on decisions about local public capital improvements. Here the players are politicans, school board, developers, and planners, each with specified payoffs and penalties resulting from the decisions they make relative to their respective public and private operations. (Thus, where CLUG stresses competition between roles of the same basic type, Metropolis emphasizes cooperation and conflict between roles of different types, including competition for the same scarce resources.) CITY is an much-expanded version of the Community Land Use Game, dealing with a larger and more complex area and introducing some additional roles. METRO is a much more complex version of Metropolis, with a simulated metropolitan environment based on real data from an actual metropolitan area (Lansing, Michigan) and introducing explicit models of overall growth, distribution of marginal growth of population, employment and land use within the metropolitan area (based on transportation access, among other factors), a market for land and housing, and models for voters' response on bond and millage referenda as well as on the election of gamed politicians. Comexopolis is a special version of Metropolis, with air pollution issues but no additional roles, developed for the Air Pollution Control Institute. (METRO has also been provided with a set of air pollution issues, though it has no explicit simulated air characteristics nor gamed air pollution control roles.) In addition, there is S.F.U.R.D.E. (University of Pittsburgh), stressing major city renewal, welfare, and similar problems. And there are probably a number of additional urban or metropolitan gaming simulations, or games, in development or even in use, which have not yet been reported to other interested parties.

Thus, the major use for gaming simulation is to provide an "environment for learning" about metropolitan processes, problems, issues, and roles. It can be used to assist the student in viewing the metropolitan area in a broader perspective than his own specialization, so that he may better put his special skills and knowledge to use. They would seem to be most useful as an integrated part of a larger educational or training program, since they do not, in themselves, provide the full detailed knowledge and skills needed for any one role. But they can be used to help the student focus his attention on the most significant features of his relationships with the rest of the metropolitan area in which he will work. They permit his gaining some initial trial experiences with his own specialized field "in vivo" rather than "in vitro" -- in the midst of the complex, dynamic, interdependencies of a simulated metropolitan area with real people playing the key roles with which he will be in most contact as a professional.

Gaming simulation can thus help students to clarify and understand decision processes, including experiencing the consequences of decisions while the situation is still fresh in his mind. They can enable the student to view each type of decision from the perspective of several key roles, enabling him to grasp to some extent "why those other people act the way they do." They provide an opportunity to familiarize the student with some of the major dimensions and orders of magnitude of key variables which are involved in significant processes and problems - the relative quantities of land, money, votes, air, contaminants, people, jobs, and so on. They can give him a chance to see how specific decision-assisting tools can be used - especially complex analytic tools like projection techniques and complex synthesis tools like programming and long-range planning. And, perhaps more important than all the rest, gaming simulations can assist the student to uncover and evaluate the goals, objectives, and decision criteria which affect the problems with which he is most concerned -- his own goals as well as those of other decision makers.

Gaming simulations meet the prime purpose of providing an environment for self-instruction. They are particularly valuable for conveying concepts about elaborate, complex systems. They enhance general learning. They can be most useful if combined with a variety of learning experiences, conventional as well as new ones. They force students to become explicit about what they are doing (and even more so when they dig into and tear apart the set of assumptions built into the simulated environment and the decision roles). They enable the trial exercise of key skills and knowledge in realistic problem situations.

For gaming simulation stresses interrelationships and interdependencies, both between decision roles and with the simulated environment. It forces recognition that past decisions have affected present circumstances and that present decisions will open up opportunities or limit them in the future. It forces recognition of real uncertainties in the environment, as well as in the behavior of key decision makers. It forces the student to try to find out what the environmental system is and how it works. It gives him an opportunity to try out a variety of analytical tools. It confronts him with the dynamics of interaction between subgroups, and the processes of distortion of information by abstraction and simplification. It gives him a beginning basis on which to build his own growing ability to judge what the significant factors are in any problem situation. It can focus his attention on the importance of long-range policy and plans.

These potentials of gaming simulation have been reasonably well accomplished in war and business games, but efforts are more recent in urban or metropolitan gaming simulations. The major limitations thus far have been the problems of creating a reasonable level of reality for such complex phenomena, the difficulties of modelling some of the key phenomena in urban areas, and the time-constraints which tend to limit possibilities for realizing all potentials such as the use of analytical tools and programming and planning techniques, as well as interrole and intergroup bargaining interactions.

The gaming simulation proposed here includes specific efforts to meet some of these limitations, but that will also depend upon careful building of this gaming simulation into the air pollution control training program. We will discuss some of these potentials and limitations in more detail after presenting some of the most significant facts about that program.

AIR POLLUTION CONTROL INSTITUTE

Growing concern with urban air pollution led to the establishment of the Air Pollution Control Institute at the University of Southern California in January 1965. Its major purpose is to design and carry out programs to train qualified personnel as technical staff, technical aides, or program directors of official air pollution control agencies. Initial emphasis has been on the training of persons already in some public agencies in specific urban areas, qualifying them to return to their agencies to participate more effectively and efficiently in air pollution control programs.

The general objectives of the APCI programs are to develop administrators who can take on responsible roles in air pollution control programs in urban areas throughout the United States, to increase abilities of the air pollution control staffs to meet growing and complex responsibilities, to aid participants to expand their present levels of competence, and to provide them with an opportunity to gain meaningful knowledge and skills to deal with such air pollution control responsibilities.

The training program includes the major areas of: engineering and physical science (chemistry, air pollution surveys, emissions from combustion, air quality standards, etc.); biological and medical (plant ecology, environmental influence, animal biology, plant science, etc.); and socio-economic and administrative (legal-enforcement, political analysis, statistics, systems design, staffing problems, etc.). These subjects are dealt with through both formal and informal methods, including field training, lectures, discussions, simulation exercises, decision-making games, role playing, case studies, and research assignments. The aim is to promote the comprehension of the interrelationship between administration and technology.

The APCI program is set up as a twenty-week schedule, with two such programs conducted each calendar year. The curriculum is designed for flexibility in scope and depth, and stresses a working understanding of air pollution control administration concepts and operations.

The engineering-science section is aimed at developing a "basic understanding of the latest and most efficient engineering and scientific air pollution control operations". The biological-medical section covers "an introduction to the diverse effects of air pollution on human populations, animals, and vegetation". Concepts of toxicology appropriate for an understanding of current knowledge of air pollution effects on human populations are highlighted.

The administrative and socio-economic section is the primary focal point of the Institute's program. The concepts, problems, and procedures of this section permeate every element of the entire twenty week program. All subjects in the curriculum are eventually focussed on and related to the ultimate administrative functions of air pollution control. Thus, the three major curriculum sections are tied together to approximate the same realistic relationships experienced in the actual work of the air pollution control administrator.

Creation, development, and administration of air pollution control programs is thus the primary emphasis, including operational goals, priorities, personnel, budget, and public relations. Students are alerted to the impact of the political makeup of communities, to political power structures, to urban economics, news media, legal processes and government institutional procedures. Critical-problem analysis and decision making concepts are stressed. Practices and procedures of courts, appeal boards, enforcement and voluntary compliance systems, and city, county, state, and federal legislative and administrative systems are dealt with. The importance of maintaining effective relations with businessmen and industrial interests and with community pressure groups is stressed, in a case study context.

The training program is being organized around a comprehensive case study model: the Model Air Pollution Control Region (MAPCORE). This is based on the Dixon/Tiller County Teaching Reference Community, developed by the Communicable Disease Center, U.S. Public Health Service, Atlanta, Georgia, and currently used there by the Hypothetical Community Training Unit, Community Services Training Section, Training Branch. This "case book" includes basic city and county government structure, population characteristics, industrial operations, and organization and operation of public health functions with supporting health data. Information on industrial emission, combustion sources, animal and vegetation that might be affected by air pollution, radiological health hazards, terrain and meteorology, and socio-economic and political pressures is being added for the APCI training program. Specific information on local government, especially local air pollution control agencies, is also being added. The completed MAPCORE is expected to present "the detailed face of the region from the views of government, industry, and citizens, plus features of geography, topography, and meteorology". It is expected to include a detailed representation of the local air pollution control system, with the Air Pollution Control Officer and his staff operating on a weekly basis over a two year sequential time span.

Within the context of this comprehensive case study model, various case problems are analyzed and solutions developed by students, to simulate the complex administrative situations faced in everyday operations of air pollution control programs. Specific training techniques include simulation exercises initiated by "in-basket" problems, requiring students to prepare, present and defend statements, reports, proposals before simulated budget committees, moot courts, hearing boards, press, radio, and television interviews, engineering and other technical bodies, civic groups, city and county councils, and special legislative committees. Students play many different roles in these exercises. And each exercise is followed by critique and evaluation sessions.

This MAPCORE approach is necessary to deal with many detailed activities. It provides a general common framework (Dixon/Tiller) around which a whole set of case studies can be organized and integrated. Yet this case study model has several recognized limitations. Primarily its use must be limited because it is static, since the hypothetical Dixon/Tiller Reference

Community is not based on dynamic models of functional relationships but rather on static reports of data and information. Once the cases have been designed, researched, tested, and written, it is difficult, time consuming and costly to alter them realistically. Thus, this reference community does not include the constantly changing patterns of urban and industrial growth which generates particular problems of air pollution in relatively short periods. It cannot deal with adaptation of the community over time, when the interrelated factors of urban & industrial growth pose massive air pollution administrative control problems.

Thus, the case study is well established as a sound method of instruction to add to and build on formal lectures and seminars. It helps considerably to integrate the curriculum. It aids in compressing a wide range of pertinent materials into the curriculum and making them meaningful to students by showing how they are relevent to air pollution control in specific cases. But for such an intensive, short term, training program, something else is needed. And what is needed should add to the MAPCORE case model and conventional techniques, but it should especially add the dynamics. And it should provide the framework for training exercises that do not have to be worked out in the detailed manner of the MAPCORE exercises. Such additional exercises should grow out of the new technique.

The APCI training program has been developed from the start with the idea that an "automated, simulated, dynamic training community" would be added to meet this need. It was proposed that an Air Pollution Control Institute Computer Exercise would use and build on the current case study system (MAPCORE). It was expected that this would not only overcome the limitations of MAPCORE but add a program sophistication and richness of its own, similar to that found in business and military games. It was expected that this approach would provide for a greater contraction and flexibility of a overloaded curriculum time span, covering extensive periods of experiences, situations, circumstances, and decisions, in a relatively shorter time period. It was intended to incorporate comprehensive and realistic experiences in an ever-changing urban setting, opening new dimensions for analytical decision making, combining administrative and technical inputs in a realistic manner. It was to provide the link between limited static case studies and dynamic realistic training. It was hoped that it would make an original contribution to the entire field of training in public health administration.

Thus, gaming-simulation was intended to provide an automated, simulated, and dynamic training community to serve as a reference case-instruction and research base for the APCI for a five to ten year period. It was to be sufficiently generalized to allow its adoption at other similar training institures anticipated by the Division of Air Pollution, U.S. Public Health Service. It was hoped it could also be applied to other professional and university public administration research and training programs.

The training exercise was to include a computer-generated air quality model, simulating air monitoring data, in the form of tables of pollutant concentrations for selected simulated locations, based on stochastically-simulated weather data and assumed distribution of pollutant sources. These sources would be linked to growth models for the area, whose output would be included as exogenous factors for the air quality simulation. And air quality output would in turn become a factor in the relative economic development of various sections of the simulated community.

This computer exercise was viewed as a dynamic environment for learning. It would use role playing and game conflicting interests. It would incorporate a voters response model or other simulation of public opinion, along with a simulated news release device. It would introduce lagged effects of decisions, revolving around forced player decisions, and including deterministic lag effects with exaggerated impact for learning effect. It would become increasingly complex with time. It would simulate several years of growth, with all cyclical variations. It would relate to MAPCORE moot court activities. It would simulate effects of broad range of interest groups, in logical sequence. And it would represent multiple governmental units with conflicting interests.

MAPCORE and the computer exercise were both aimed at involving students as early and effectively as possible in a series of activities similar to those which a new air pollution control officer will find himself as he assumes his new position. The training program has three elements: the hypothetical Dixon/Tiller County; the framework of simulation, to include the rationale for the linear development activities scheduled to occur in sequences in which students will find themselves; and the "igniters" which spark the students and start them on their activities in the simulation. The overall aim is to make all activities as dynamic and realistic as possible.

APEX IN THE APCI TRAINING PROGRAM

The Air Pollution Exercise (APEX) described in this report is intended to provide an operational dynamic gaming simulation for the APCI training program. Its major aim is to assist students in understanding and appreciating the complexities of the overall city and metropolitan environment, the problems and perspectives of other decision makers in that environment, and the potentials and limitations of an air pollution control program which must compete with many other problems and issues for the attention of those decision makers as well as for scarce resources.

With this emphasis on the overall metropolitan environment, it is not expected that the APEX gaming simulation will deal in detail with the technical knowledge and skills required for air pollution control or with all the details of the administrative operations of the air pollution control agency. Other parts of the program, such as the MAPCORE comprehensive case model and the more conventional lectures, seminars, field training, and research assignments are expected to deal with these very important parts of the knowledge and skills required by the air pollution control staff. The gaming simulation will concentrate on the larger metropolitan context within which air pollution control problems and issues must be resolved.

For similar reasons, the APEX gaming simulation will not include full details of the reality of air characteristics, contamination levels, and control measures. It must include enough detail to make the air pollution problems and issues realistic in the metropolitan context. It will include a representative, not predictive air mass model in which contaminant concentrations are approximated in various parts of the urban area. The model will generate realistic-looking air data, such as might be obtained from monitoring stations and spot inspections.

For similar reasons, APEX will not include the full and detailed operations of an air pollution control agency and staff. It will include the role of the air pollution control officer (APCO) with sufficient reality to "ring true" to experienced professionals within the general framework of the simulated and gamed metropolitan area. But it will not reproduce detailed daily operating routines, detailed breakdowns of budgetary allocations, nor detailed division of labor among air pollution control staff.

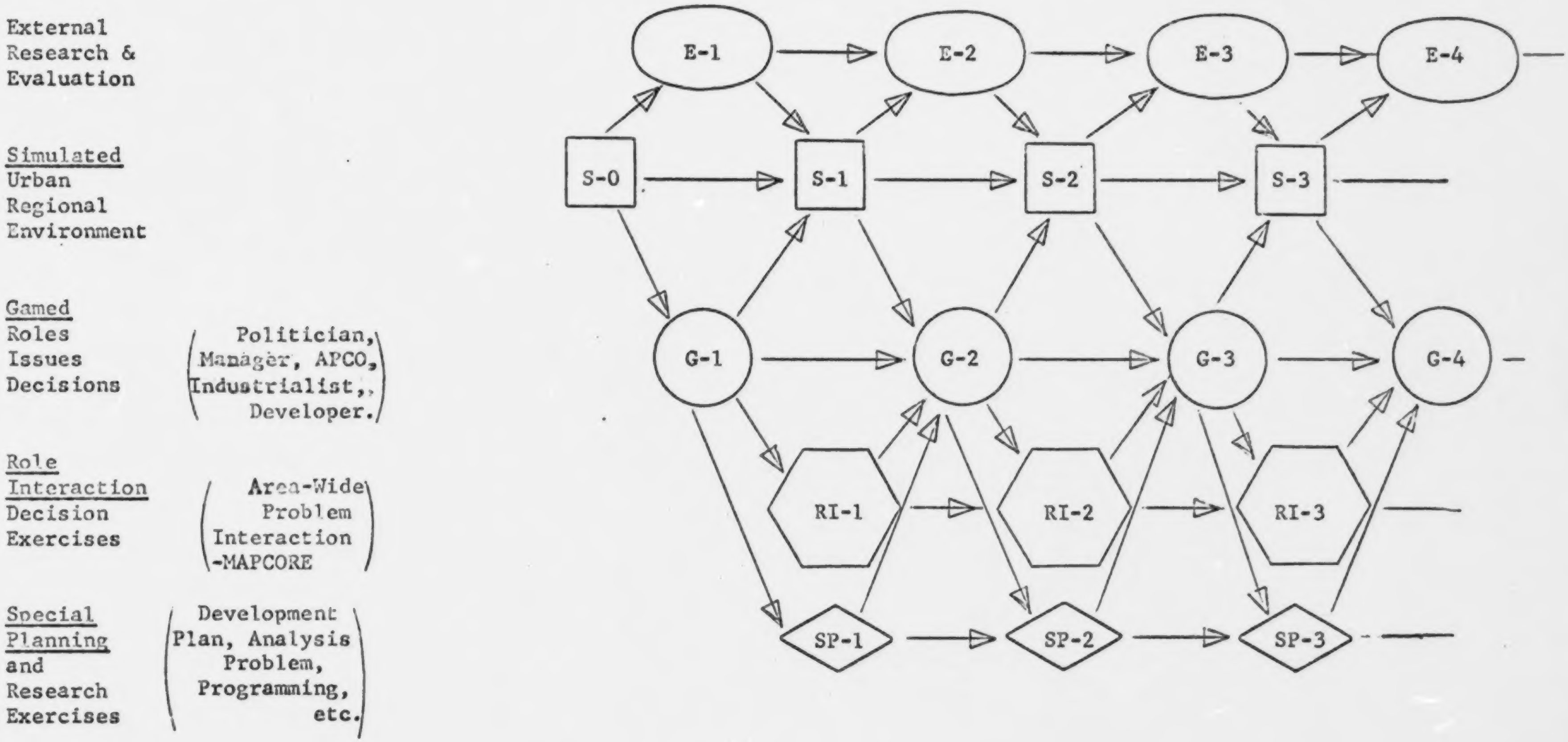
This general level for the APCO role is critical to the balance of the gaming simulation. Air pollution problems and issues cannot take up most of the time of all decision roles, for that is far from true in the real world. Even for the APCO, the emphasis in APEX will be on his interactions and transactions with the other decision makers and the simulated environment at the level of their major annual decisions and the most significant overall changes in the environment. Thus, though the APCO will spend most of his time dealing with air pollution control problems and issues, he will deal more with his own program and budget decisions, his major interactions with public and private decision makers, and his attempts to analyze the general meaning of simulated air characteristics data.

For the more detailed consideration of technical problems, it is expected that APEX will "trigger" specific MAPCORE exercises, including some dealing with the political, economic, and legal resolution of problems as might occur in public hearings, technical hearings, and court cases. At such times the time-scale of APEX would give way to something closer to real world time-scale, so that specific problems and issues could be dealt with in much greater detail. Figure 1 shows how these special exercises might be fitted between the regular cycles of the APEX gaming simulation. Detailed development of MAPCORE exercises to be used in conjunction with APEX are a seperate research activity to be undertaken by the project staff at the University of Southern California.

These special exercises might also include specific sessions concentrated on the development of long-run air pollution control programs, detailed application of special models for projecting air pollution potentials, special player interactions to deal with specific problems or issues raised in regular APEX cycles, and so on. Thus, it is expected that there will be special problems raised in the gaming simulation which will call for between-cycle special exercises, in addition to the more

Figure 1

GENERAL APEX INTERACTIONS AND CYCLES


External Research & Evaluation
Simulated Urban Regional Environment
Gamed Roles Issues Decisions
(Politician, Manager, APCO, Industrialist, Developer.)
Role Interaction Decision Exercises
(Area-Wide Problem Interaction -MAPCORE)
Special Planning and Research Exercises
(Development Plan, Analysis Problem, Programming, etc.)
E-1
E-2
E-3
E-4
S-0
S-1
S-2
S-3
G-1
G-2
G-3
G-4
RI-1
RI-2
RI-3
SP-1
SP-2
SP-3

formally and fully-worked-out MAPCORE exercises, which can also be triggered from gaming-simulation activities.

Although it is intended that the gaming period will provide sufficient time for the making of the required decisions, it is very likely that participants will spend some time beyond this discussing what they have just decided and planning ahead for what they think will come up next cycle. It may be desirable even to schedule some specific time in which they can interact in this way, and this kind of interaction could even become a major kind of exercise between cycles, like MAPCORE. Thus, if the equivalent two half days per week are not involved in MAPCORE exercises (assuming that the total time for APEX plus other simulations may be two days each week), then perhaps that additional time could be worked up as scheduled periods for interaction or even for special kinds of analysis. For example, this may be a time to focus on the problems of developing a long-range program for air pollution control in the APEX simulation, to be introduced and decided upon at some subsequent decision period, then followed by the APCO and other decision makers in following gaming periods. Since it is difficult to find time for such long-range planning and programming in the busy decision period (as in the real world), any concentration on it will depend upon some such arrangements.

In order to be able to develop a practical, workable gaming simulation it is necessary to abstract and simplify the set of relationships which exist in the real world. As suggested for the APCO role and the air data above, the limitations of workability also mean that APEX cannot include all of the specific roles which might be encountered in a real metropolitan area. Thus, APEX will include only a handful of gamed industrialists, whose specific operations lead to particular pollution problems, with the rest of the industrial sector being simulated. Similarly, the chief legislative bodies of the major local governments will be included, along with a chief administrative officer or manager, but APEX will not include the many additional elected and appointed officials and some local governments will be simulated. And school boards, although critical to many local problems and issues, will be simulated rather than gamed in APEX.

In other words, this APEX gaming simulation is being developed as a balance between the overall characteristics of a metropolitan area, with many other problems and issues besides air pollution, and the more special characteristics related to air pollution and its control. Striking the most effective balance will continue to be one of the greatest difficulties in the development of APEX as a practical, workable gaming simulation. Here it is important to point out that workability for such a gaming simulation has three major parts -- first, there is the "computer-workability" of the various simulations which are to be developed as computer programs; and second, there is the "gaming-workability" of the various roles and interactions between roles which are gamed; and third, there is the combined "computer-gamed workability". Each of these has its own difficulties, but APEX has the additional difficulty of developing the gamed roles and interactions that can be grasped by APCI trainees and that will fit into and complement the rest of their training program. Each of these places severe limitations on the levels of complexity that can be included. In effect, given some overall limitation on complexity, such a gaming simulation must divide this among its parts.

APEX RUN SEQUENCES

Assuming that each individual APCI training program runs for twenty weeks, it is suggested that the APEX gaming simulation be made an integral part of that program on a bi-weekly basis. Thus, APEX would be run as often as two four-hour sessions each week, giving a total of forty APEX sessions. It also assumed that there will be an appropriate amount of time each week devoted to MAPCORE and other special exercises, some of which can be triggered by problems and issues raised in APEX.

Past experience suggests that it is not advisable to start immediately with the full-scale APEX gaming simulation, but rather to build up to it by several preparatory and introductory steps. For these purposes it is suggested that the APCI students start with some introductory sessions on orientation to simulation and the way in which it will be used in APCI and the APEX simulation. This would be followed by participation in such simpler gaming simulations as the Cornell Land Use Game and Comexopolis. In all, it seems likely that about four weeks of such introduction will be advisable, before starting into APEX.

The remaining sixteen weeks would be devoted to runs of APEX, including essential buildup and critique sessions. The latter might take a total of four weeks altogether. Assuming that each simulation session would permit the run of one cycle (year) of the APEX gaming simulation, this would permit one continuous set of 24 runs. However, this would not be desirable. Instead, it is suggested that APEX be broken down into three separate rounds of eight cycles each. These three rounds will permit the achievement of three major purposes: (1) Students can switch roles each four cycles, so they can experience several different general perspectives as well as several different sets of problems and issues on air pollution and its control, (2) the simulated air characteristics can be altered for each eight-cycle round, so that students can experience different air mass and contaminant types and levels within the framework of the same simulated socio-economic-political metropolitan area, and (3) potentially this will also permit the "re-recreation of history" by returning students to the same roles and decisions made in a previous round, but with the opportunity to make new decisions based on what they learned from an earlier round to see how some altered decisions might affect the course of events.

The possible structure of the full schedule of APEX within the twenty week APCI schedule might look something like that shown in Figure 2. The four introductory weeks would include initial lecture and discussion, probably including films and video tapes, as a general introduction to gaming-simulation. Then students would participate in an initial session (about 5 cycles) of CLUG, after which they would spend a group session developing a land use plan for the CLUG community. Then they would play one additional session (about 10 cycles) of CLUG, operating within the constraints established in the development plan. Then there would be a lengthy session of Comexopolis, permitting about seven cycles with a final critique.

The first round of APEX also has a necessarily introductory character, since students will require some time to get acquainted with the various kinds and forms of both computer output and their own decisions and roles. It is expected that this will take two or three cycles of the first APEX round, so that full decision role activities will not start until the third or fourth cycle of that first round. As suggested in Figure 2 this first round will be followed by two full sessions on critique and discussion.

The second and third rounds of APEX should not require the full introductory phase of the first round, since students will already be acquainted with the major characteristics of the gaming simulation.

FIGURE 2

APEX in the APCI TRAINING SCHEDULE

(assumes 15-25 students, 20 weeks, two 4 hour sessions per week, plus MAPCORE II exercises).

WEEK		SESSION "A"	SESSION "B"
1		NO SIMULATION - ORIENTATION TO APCI	
2		INTRODUCTION TO SIMULATION	CLUG
3		DEVELOP PLAN FOR CLUG	CLUG UNDER CONSTRAINTS
4		COMBINED SESSION -6 HOURS - COMEXOPOLIS	
5		APEX CYCLE 1	2
6	Round 1	3	4
7		5	6
8		NO SIMULATION. CRITIQUE AND NORMAL CLASS SCHEDULE	
9		APEX CYCLE 2	3
10		4	5
11	Round 2	6	7
12		8	9
13		NO SIMULATION. CRITIQUE AND NORMAL CLASS SCHEDULE	
14		APEX CYCLE 2	3
15	Round 3 (Opitional)	4	5
16		6	7
17		8	9
18		NO SIMULATION. CRITIQUE	
19		NORMAL CLASS SCHEDULE	
20		NORMAL CLASS SCHEDULE	

Thus, full role operations should start right off. (We have shown these rounds starting with cycle two, suggesting that cycle one is an introductory one that is eliminated here. Each of these rounds is also followed by two full sessions for critique and discussion.

As shown in Figure 2 it is suggested that two weeks (four sessions) be left at the end for overall critique and discussion (or possibly even for some other final windup activities in the whole APCI program). However, this additional time at the end provides room to cover any slippage that might take place in the rather tight earlier schedule of APEX rounds and cycles. It is probably inevitable that initial use of APEX in the APCI program will encounter problems, whether in computer operations or in the gaming sessions, which might make it desirable to take somewhat longer than was initially expected. Thus, this extra time at the end may also be considered a kind of cushion to be used to permit some slack at earlier points as that might be required.

The APEX gaming simulation sessions, as discussed here, are primarily the gamed decision role portion of APEX, which would then take place during regular scheduled class sessions. Each such session would start with computer output, providing students with information about the simulated metropolitan environment which raises problems and issues and upon which they can base their subsequent decisions. Each such decision session will end up with a set of decisions which have been made by the students playing the various roles. These decisions, of course, become the input to the computer for its processing operations. And such processing can be accomplished at any time prior to the next gamed decision session. (Gamed-computer relations for air characteristics will be somewhat different, as well as discussed shortly.)

This means that, if gamed decision sessions are scheduled for Tuesday and Friday mornings, for example, the computer operations based on decisions from the Tuesday sessions must be accomplished sometime prior to the Friday morning session. Technically, then, the computer processing could be accomplished Thursday night, but it is suggested that this be carried out early enough to allow time for possible difficulties in running the computer programs (which seems to be almost inevitable in the operation of computer programs as an integral part of such a tight schedule.) In other words, it would be best to do the computer processing on Tuesday afternoon or Wednesday morning.

One other constraint may enter into the timing of computer processing, however. If some APEX decision sessions are expected to include some specific problem or issue which triggers a MAPCORE exercise or some similar special decision exercise, it is possible that exercise may also end up with computer input which must be included before computer processing resulting in the computer output for the next major decision session. This possibility must be considered in scheduling computer processing operations between major decision sessions, although it is most likely that the special exercises, like MAPCORE, will feed directly into the next major decision session, without intervening computer input. That is, it seems likely that the results of the MAPCORE exercises may become additional information to be used by students in their decision roles rather than providing inputs directly to the computer.

The three major APEX rounds will all involve the same basic simulated socio-economic-political environment, but will vary on the basis of climate and meteorological conditions that are assumed to exist. It is possible that the initial state for air monitoring equipment may also differ, and that different terrain and topology may also enter in. In any case, students will have some opportunity to deal with the air pollution problems of a typical northern climate, with its winter heating season, as well as with some climate involving more and longer seasons of sunlight and photochemical effects. Although maintenance of the same socio-economic-political environment is admittedly somewhat artificial, this offers the possibility of concentrating on climatic and air characteristics and air contamination without also worrying about a completely different total environment.

The suggested pattern of operations for APEX would also include the shifting of roles every four cycles, so that each student would have an opportunity to participate in most of the decision roles. Thus, he might be an APCO at one time, an industrialist at another, a city politician another, and so on. Each student would play six different roles (two in each APEX round), making it possible for him to cover each major type, with some variation among types of political jurisdiction as well.

Shifting roles and the possibilities of different climates are intended to make APEX more useful within the APCI training program. However, as much as possible, these should be options available to the APCI faculty, so that they can experiment with the best ways to use APEX and make variations as required to fit this gaming simulation into the total training program. Successful operation of APEX must be measured by how well it fits the training requirements, which can certainly be much better worked out and evaluated by those responsible for the total training program.

It is also important to recognize that APEX and the attempt to build such a gaming simulation into this kind of training program are both experimental. It should be expected that both APEX and the training program will have to grow and develop as they adjust to the fundamental aims of providing better training for air pollution control professionals. There will undoubtedly be ways, even at this point, in which those experienced with the training program will suggest that APEX must be developed to meet their needs. But there will undoubtedly be even more changes required when some form of APEX is sufficiently completed and workable for it to be put into actual use in the training program. Then some things that seem most desirable for the training program will be possible to do, while others will be difficult or impossible. In any case, it should be expected that many adjustments will have to be made.

Similarly, if the APEX gaming simulation does prove to have most of the potentials seen at this time, and if sufficient changes can be made to make it an integral part of the APCI training program, then it should also be expected that the training program, and its scheduling, may have to be adjusted in some ways to the format of APEX. At this point it is impossible to say what such adjustments might be, but the APCI staff can probably make some estimates based on their experience with trying to fit their program around the MAPCORE exercises. It may be that the specific timing of MAPCORE exercises will have to be adjusted to APEX, or that APEX will have to be adjusted to call out MAPCORE exercises in some order which is more logical from the perspective of the overall training program.

PROPOSED METROPOLITAN SYSTEM

A gaming simulation such as APEX can be looked at as containing two major parts, each with several subparts, and the essential links which tie the system together. The most fundamental base is the simulated metropolitan area, with its data and models representing the simulated public and private sectors. Around this simulated base is built the set of key decision roles which are gamed, and those also involve both the public and private sectors. These two major parts, and their several subparts, are linked together by computer output of information about the simulated environment, (which becomes a key input for the decision roles), and gamed decisions (which become key inputs to the computer simulations). These key links are describable in terms of the problems, issues, and decisions to be dealt with and the interactions among computer data and models, among decision roles, and between computer and roles.

The *simulated metropolitan environment* of APEX includes a key set of data about population, employment, land use, public facilities and air characteristics. Much of this data is organized into models stating dynamic functional relationships involved in the growth and distribution of population and employment, the sale of real estate, the response of voters to bond issue and millage referenda and to candidates seeking election, and the buildup of contaminant concentrations in response to general air characteristics and to the emission of contaminants in various sections of the metropolitan area. This simulated environment raises problems and issues about which decisions must be made, and it responds to the specific decisions that are made by key decision makers.

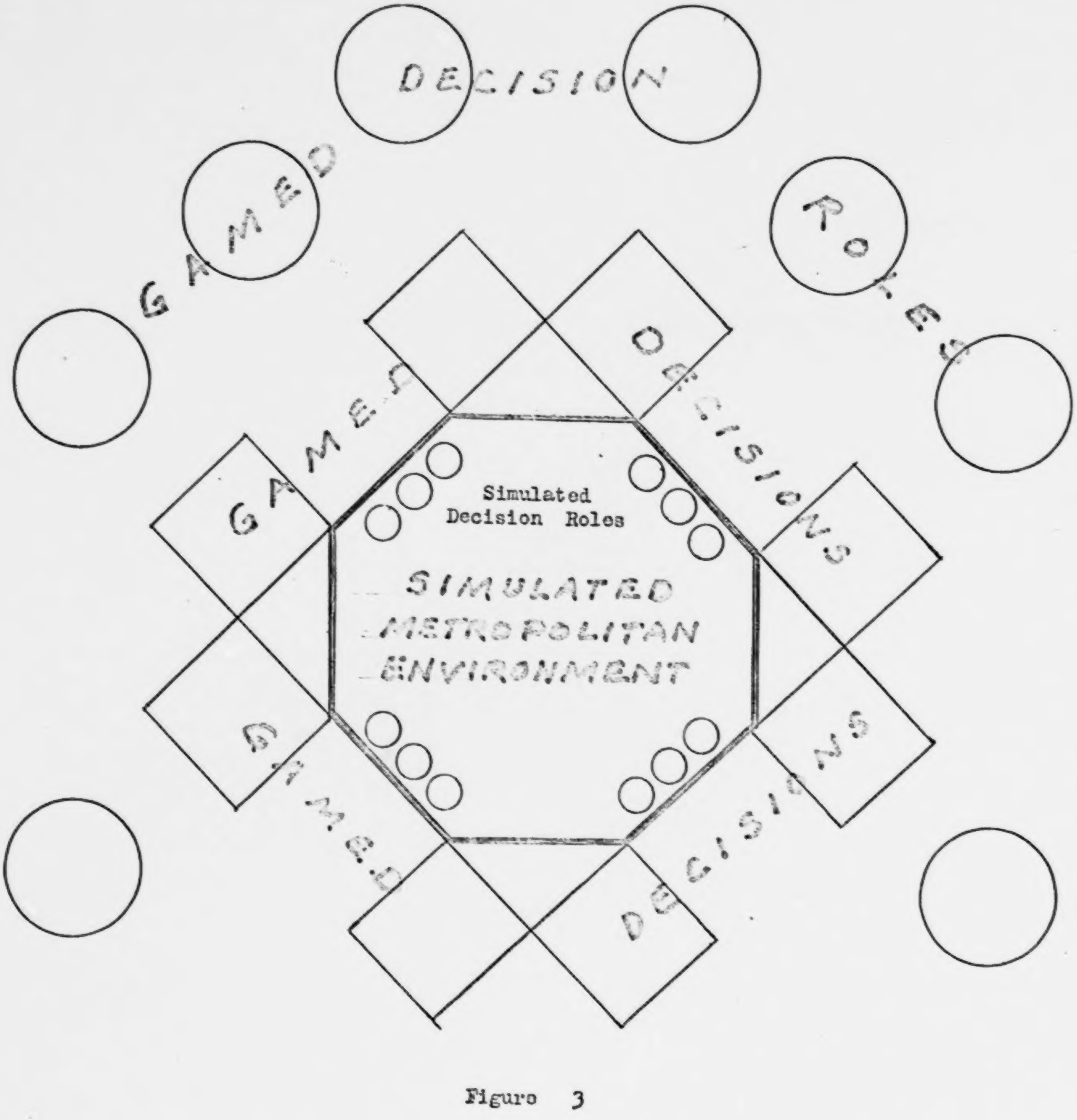
The set of *gamed decision roles* is built up around this simulated environment, with critical interactions among roles as well as between each role and those parts of the environment which affect it most. The simulated environment provides the richness of opportunities, problems, and issues with which the roles must deal. They must make both routine, periodic decisions, such as annual budgets, tax rate, and capital improvement projects, and irregular decisions on problems and issues arising out of the changing environment and the growing set of interactions among gamed roles. Their decisions will have impact on the environment, and the environment will "bite back," facing them with further decisions about problems and issues which their own prior decisions have partly created.

Thus, game decision makers are forced to live with the results of their own decisions on the environment, one or several cycles (years) later. And each player must also live with the results of decisions made by other players, so that he will increasingly see the value of trying to influence those decisions, by persuading or forcing other players to make their decisions in certain ways. In this way, the dynamic relations among players, and between players and their simulated environment, builds up over time in the gaming simulation.

Figure 3 shows a simple view of the relations between the simulated environment and the gamed decision roles, including the additional feature that some decison roles are also simulated.

METROPOLITAN SECTORS, SIMULATED AND GAMED

Before describing the major simulated and gamed parts of APEX it is important to present the overall configuration, showing how some parts of the public and private sectors are simulated and some gamed. This particular pattern is proposed for APEX, as an air pollution gaming simulation, so that it has features unique to that purpose. At the



GAMED DECISION ROLES
GAMED DECISIONS
GAMED DECISIONS
GAMED DECISIONS
Simulated Decision Roles
SIMULATED METROPOLITAN ENVIRONMENT

Figure 3

GENERAL FORM OF GAMING -- SIMULATION WITH GAMED DECISION ROLES, SIMULATED DECISION ROLES, AND COMPUTER -- SIMULATED METROPOLITAN ENVIRONMENT same time many of these characteristics might also hold for other uses of this same gaming simulation. The major configuration is shown in Figure 4.

Public Sector

In APEX the key local governments of central city and county will be gamed, while the remainder of the county outside the boundaries of the central city will be considered to be included in five simulated municipalities, representing the developed suburbs and developing townships of the county. Thus, APEX deals with an urban and urbanizing metropolitan area, with outlying portions being primarily agricultural. Figure 5 maps these units.

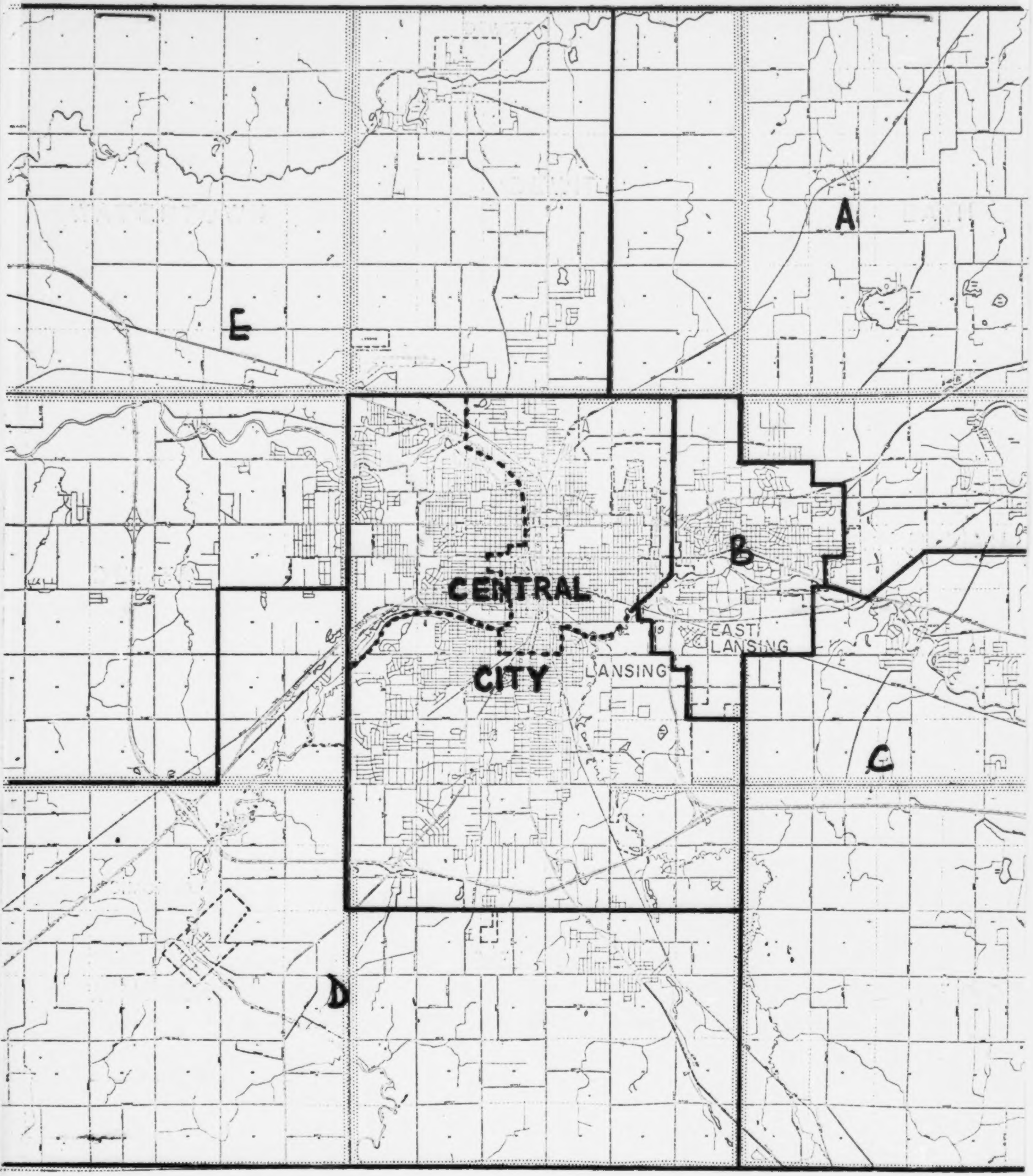
The *Central City* is a fully incorporated city. Its government has responsibility for directing its own development and for providing public services and facilities -- police and fire protection, parks, sewers, water, and so on. It also has authority to levy property taxes and issue bonds to finance its operations, subject to general state law. It must compete for funds with the Central City School Board, which levies taxes on the same property base. With the exception of public health and welfare, which are provided by the County, the Central City provides all general government services usually associated with local government. But the Central City does *not* have responsibility for air pollution control, which is part of the County health operation. Decisions in the Central City are made by its gamed Politicians, representing three city wards. A City Manager serves them as staff. (See Gamed Decision Roles).

The *County* includes the whole metropolitan area (about 320 square miles). The County government has the primary responsibility for pro-

FIGURE 4

PUBLIC AND PRIVATE SECTORS, GAMED AND SIMULATED

	Simulated Metropolitan Environment	Gamed Decision Roles
Public Sector		
Central City		Politician, Manager
County		Politician, Manager, APCO
Municipalities	X	
School Boards	X	
Private Sector		
Industry	X	Industrialists
Business		
Developers	X	Developers
Other	X	
Households	X	


A
B
C
D
E
CENTRAL
CITY
LANSING
EAST
LANSING

viding public health and welfare services to all residents in the area. Air pollution control is a county responsibility, dealt with through its gamed Air Pollution Control Officer, its gamed Health Directors, their staffs, and the gamed County Health Commissioners. In addition, the County government provides some services and facilities, on a contract basis, to the simulated municipalities. The County is authorized to levy taxes on all property within its boundaries (including the Central City) and to issue bonds to finance capital improvements for which it is responsible. Since it is responsible for planning and zoning for the entire land area outside the Central City, and since the Central City is largely built up, the County is the key local governmental body dealing with future growth of the area.

Seven gamed Politicians serve as a County Board of Commissioners, and they also function as the County Health Commissioners. One Politician is elected from each of the five simulated municipalities, and two are elected from the Central City. A gamed County Manager assists the Politicians, and he is also the Health Director to whom the Air Pollution Control Officer reports.

The County government will be in direct competition with the Central City, the simulated municipalities, and the simulated school boards for general property tax revenues, since County property taxes are added to those which are paid to each of the municipalities.

The five Simulated Municipalities cover the developed suburbs and developing townships outside the Central City. Each is an incorporated area with a municipal government having full taxing powers and responsibilities for providing services and facilities to its residents. However, in APEX, it is assumed that these municipalities contract with the County government to provide some of the services and facilities which cannot be provided efficiently by small, separate units. They all contract with the county to carry out planning and zoning and to provide capital facilities such as streets, sewers and water mains (although such facilities are not provided in all sections of these simulated municipalities). Some units also contract for fire and police protection, parks and recreation, libraries, and other services, while others provide some of these for themselves (primarily the developed suburbs). Thus, these simulated municipalities will each have different kinds and levels of public services and facilities, and different configurations of arrangements for providing these services themselves or by contract with the County. As in the Central City, each municipality is in competition with its simulated school board for funds from the same property tax base.

There are independent simulated school boards in the Central City and in each of the five simulated numicipalities. These school boards can levy taxes on the general property tax assessment base for operating and capital expenditures. They must go to the electorate for increased millages for operating budgets and for bond issues for specific capital facilities. Specific data on critical operating and fiscal characteristics of these simulated school boards will be simulated so as to include the educational operations which consume the largest part of local tax revenues and to provide for realistic competition between gamed and simulated county and city politicians and school boards for scarce funds.

Private Sector

The private sector is represented in APEX primarily by industrialists and developers. In each case, one set is gamed while all of the remainder operating in the metropolitan area is simulated. Gamed industrialists and developers also represent the private "power structure" or "elite" decision makers in the metropolitan area. As such, their opinions are considered carefully by public sector decision makers, as registered through the "elite opinion poll" or through interactions during gaming.

The industrial subsector includes a set of gamed industrialists, viewed as the local plant managers of industrial firms which are the major potential contaminant-emittors of the metropolitan area (power plant, oil refinery, cement plant, dry cleaner, chemical plant, steel plant, and major apartment and office building firm). Each industrialist thus represents one firm, but he may deal with operations at several locations within the metropolitan area. The remainder of the industrial sector is simulated, but it will consist of a specific list of all industrial firms in the region with information about their locations, operations, and especially about their contaminant emission characteristics (keyed to SICC class of firm). In addition to a cross section of industrial firms, industrial sector includes one major manufacturing firm (Oldsmobile, in Lansing) with operations at several locations, which may be included as a gamed industry. All gamed and simulated industries will have their levels of operations partly determined by exogenous factors, through the effect of a simulated outside demand, but the gamed industrialists will also be able to vary their levels of operation by their own decisions.

The business subsector is represented primarily by gamed and simulated developers, whose primary concern is with buying and selling land, developing that land for residential, commercial or industrial uses, then selling it. Gamed developers operate in relation to a simulated market, representing the demand for various types and prices of housing and other private developed land in various sections of the metropolitan area. Simulated developers take up any remaining demand which gamed developers do not meet. The remainder of the business subsector, including all other kinds of retail and wholesale business and various services, is simulated through the increase of commercial land use and assumed tax assessments.

The household subsector has five simulated household types, based mainly on socio-economic characteristics but also closely related to voting responses. This household subsector represents the resident population, labor and school-age population of the metropolitan area, and it grows and changes as a result of changes in the economy and operations of the real estate market for housing.

SIMULATED METROPOLITAN ENVIRONMENT

The simulated environment in APEX is made up of data about people, about economic values, about physical facilities and materials, and about natural air and land. This data is organized in a variety of forms, including models expressing dynamic functional relationships so that changes in one kind of data will affect others over time, accounts of various kinds which tabulate the inventories of facilities or monetary values for various facilities and players, several kinds of listings (such as newspaper headlines) which are called out in specified circumstances, and many computer subroutines linking together the major segments of the simulation.

The basic dimensions of this data and these models are drawn from the real world metropolitan area of Lansing, Michigan. Thus, many of the functional relationships, including responses of voters to tax millage and bond issue referenda, have been calibrated on the basis of real data about Lansing. This real-data base is important primarily because it means that most of the simulated data and relationships are realistic, at least in terms of the order-of-magnitude of the dimensions and relationships being dealt with. Difficulties of getting some kinds of data means that these relationships may not be accurate for small areas of the simulated metropolitan area, but the overall, gross, aggregate-level data and relationships are substantially those of a real community. This has distinct advantages over any simulation which is based on some entirely hypothetical community, since builders, operators, and players can be reasonably assured that the major dimensions and relationships are at least "in the right ballpark".

For APEX, however, the introduction of air characteristics, including air contaminant emissions and levels, will not be drawn directly from the real characteristics of Lansing. Here it is necessary to admit that Lansing does not have all the typical pollution problems, nor the variety of climates which seem desirable as an air pollution exercise. Thus, the air characteristics for this simulated metropolitan area will be hypothetical. This is also required for the option of assuming different total natural climatic and meteorological environments so APEX players can face the problems of quite different kinds of pollution.

The APEX simulated environment is a very high level abstraction, including a very gross simplification of the real Lansing community. What has been abstracted out is that which is deemed most important for dealing with such area-wide problems as public capital facilities, local governmental operations, and air pollution. Considerably greater detail would be needed for the inner part of the central city, for example, if such a gaming simulation were being developed to deal with urban renewal or social welfare. Other detail would have to be added to deal with water supply and water pollution (though that might be done in a fashion somewhat similar to what is suggested here for APEX), and still further detail would be required to make schools or transportation or retail shopping a major kind of problem and issue within such a gaming simulation. At this point in time it seems impossible to include all the details required for the full set of metropolitan problems in one simulated environment, since the levels of complexity being dealt with are already close to the limits of workability. Perhaps further experience and development will permit much richer simulated environments in the future, with the potential of dealing more adequately with the important interdependencies between the full set of problems.

The APEX simulated environment can be looked at in two ways. In the first place it is built up from several major kinds of data. And in the second place this data is organized into a set of computer-simulated models, accounts, listings, and subroutines (especially those required to link the others together). Initial attention will be focussed on the data, followed by discussion of models, and so on.

Data Environment

Only a small part of reality can be used in the simulation, if it is to be workable. The relatively few data items that are chosen set significant theoretical, philosophic and operational boundaries on what the specific simulation can mean. APEX operates with a data environment that has been selected to represent the most significant quantifiable dimensions of a typical middle-sized American metropolitan area.

People are the most important and difficult element to deal with. A metropolitan area exists for its people, and they determine what it will be. Capturing the great diversity of even a small urban area is extremely difficult. In APEX the household is the basic element of population (already a higher level of abstraction than the individual person). Households are the units of reference for housing, employment, school population, and even voting response. Households are divided into five socio-economic types (described in more detail in the Appendix). Partly on the basis of empirical evidence and partly on the basis of theory, each household type is assumed to have specific characteristics related to employment, housing types, school population, voting, and so on. (These assumptions are built into the models discussed later.)

APEX deals with the special characteristics of school population by specific age groups, related to household types. These become critical to the generation of simulated school expenditures and bond issues and millages for schools which other public expenditures and taxing measures must compete with, as seems warranted by the large part of local taxes and expenditures which go to support public schools (normally over 60% of all public funds flowing through a community are spent by the school board).

In APEX employment (jobs) is the primary indicator of economic activity and economic well-being of the metropolitan area. Changes in employment are the basic driving force for growth in the simulated socio-economic environment, leading to changes in households, demands for housing and commercial services, demands for public facilities and services, voter response, and so on. Thus, APEX is built around some relatively simple "economic base" concepts, with exogenous, basic, exporting industry serving as the primary growth determinant, and endogenous, nonbasic, "service" industry and commerce assumed to expand or decline in response to changes in basic employment. Employment is broken down into industrial and commercial, and the major employers are carried separately with changes in their employment due to outside circumstances being the major linkage between the APEX simulated environment and the "rest-of-the world." (The real Lansing metropolitan area has the primary employers of state government, Michigan State University, and the Oldsmobile automobile production operations. In general terms, these can be viewed as any major office-operation, a major research or educational operation, and a major industrial operation. Their actual operations, especially for emission of air contaminants, can also be viewed in this way.)

People are also viewed as voters, responding to proposed bond issues for public capital facilities and to proposed increased tax millages for operation of local government and schools. Their voting attitudes are assumed to be also characterizable by their household types), so that responses to specific issues will depend upon the numbers of households of the several types in a given voting jurisdiction. Similarly, voters are categorized by household types in assuming certain relationships for voting on the election of candidates.

In APEX land use is the term used to refer to the man-made, privately-owned physical environment. It represents the land and buildings as a composite of activity (what takes place on the land or in the buildings) and facilities (the kind of buildings or structures on the land). Land use is broken down into the categories of vacant and improved property, with a further breakdown of the latter into residential, commercial, industrial, public and agricultural land. There are also additional categories for zoning (legal definition of what kind of activity or structure is permitted on the land) so that there is a considerable variety of combinations of vacant and improved land, actually used in various ways, and actually zoned in various ways.

Land use data is closely linked to population and employment data. Thus, land use data will include the numbers of households and empolyees of specific categories, translatable to acreage terms by simple density formulas. Vacant land is reported in acres by land use category, as well as by zoning category. (These details are spelled out more fully under "Gaming-Computer-Links".)

One chief type of economic data is the monetary value of land (and buildings). Here two values are included, the assessment value for tax purposes and a market value for buying and selling purposes. The residential market values are carried in three distinct price categories (low-medium-high) as required to add reality to the real estate - development part of the gaming simulation.

Public facilities in APEX are chiefly these provided by local government or school boards, including primarily streets, recreation facilities, water facilities, sewer facilities, and school facilities. (Air monitoring facilities required by the Air Pollution Control Officer for his operations may be considered by him as capital facilities.) These local public capital facilities are carried to reinforce the focus on public policy and public operations in the APEX gaming simulation.

Another chief economic value is the total dollar value of each public facility type in each part of the metropolitan area. These values are depreciated over time to cover the deterioration and obsolescence of existing capital plant. A capital plant index of public capital investment in each type of facility is carried for each part of the metropolitan area, along with a composite capital plant index covering all facilities taken together. These indices provide a basis for comparing various subareas and thus a qualitative as well as quantitative picture of how well each area is being provided with public facilities (and presumably also the public services for which they are needed).

Tax assessments are another form of economic value carried for the

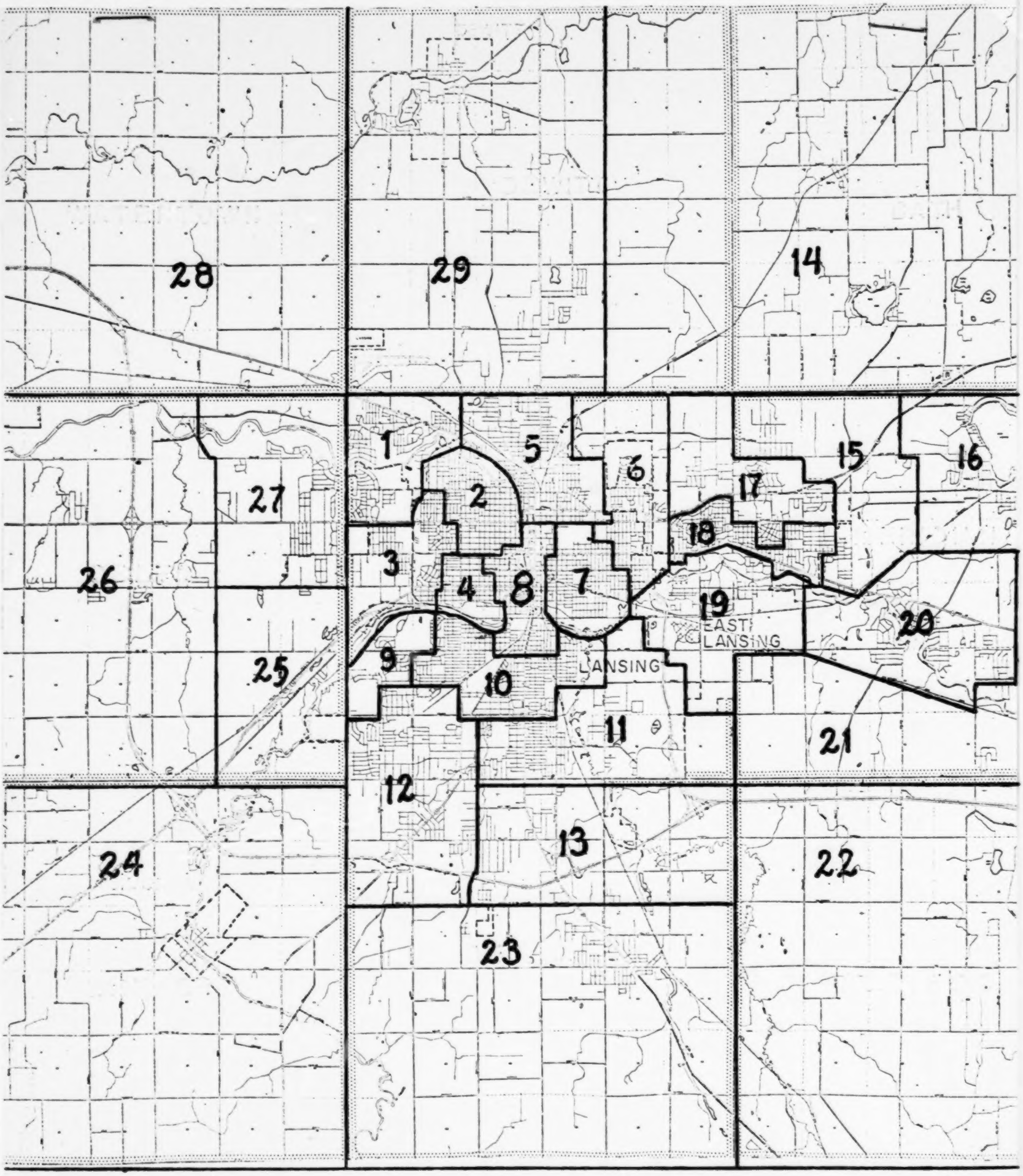
Figure 6

Correspondence Between Analysis Areas and Jurisdictions

Political Jurisdiction	Analysis Areas
1. Central City	1-13
Ward 1	1-4
Ward 2	5-8
Ward 3	9-13
2. Municipality A	14-16
3. Municipality B	17-19
4. Municipality C	20-22
5. Municipality D	23-25
6. Municipality E	26-29

Analysis areas are the smallest data units in APEX. They correspond roughly to census tracts, or combinations of census tracts. Thus, the social and economic characteristics of the population are roughly comparable, as is the approximate number of people in each analysis area. The twenty-nine APEX analysis areas, shown in Figure 7, are grouped into the six municipal jurisdictions, which cover the entire land area of the simulated metropolitan environment. Combination of the appropriate analysis areas for specific data tabulations and calculations leads to accumulated totals for the five simulated municipalities, the central city, and even the three separate wards of the central city. The grand total for all analysis areas gives data for the county or the metropolitan area.

2-B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LANSING
10
11
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12
24
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23

A.P.E.X. ANALYSIS AREAS

several parts of the metropolitan area. These become the basis for determination of tax rates, as any given area grows in housing, commerce, and industry (which pays taxes) and as it decides on its proposed expenditures and tries to get various bond issues and millages approved by the voters.

In APEX the natural environment is represented partly by land, since it deals with space (but primarily in terms of its economic value as a scarce resource). But the primary natural environment will be the air. Here the data will be general air characteristics, such as wind speeds and directions, temperatures, humidity, sunlight (cloudiness), varying over time, and the more specific levels of concentration of contaminants of various kinds in several parts of the metropolitan area. Contaminants will be considered to be mainly man-generated, resulting from various industrial, commercial, residential, public, transportation, and other human operations in various parts of the metropolitan area. Thus, contaminant generation will be closely linked to land use locations, activity types and levels (households, specific types of industries, specific public operations like incinerators, and specific employment and commerce-centered activities like journey-to-work).

Modeled Environment

The computer-simulation models in APEX are the dynamic heart of the simulated metropolitan environment (see Figure 5) and one of the chief differences between APEX and such static, hypothetical communities as Dixon/Tiller County. They simulate the dynamic functional relationships of the interacting systems of economic and political processes in the metropolitan area. Six general models make up the major part of the modelled environment in APEX: GROW for exogenously-generated employment and population growth, SPREAD for general employment and population growth and for distribution of this growth to various parts of the metropolitan area, SELL representing the residential real estate market, VOTE for voters' response to various bond and millage referenda, ELECT for voters' response to the election of candidates for local public offices (politicians), and AIR to represent air characteristics, including contaminant levels. In addition to this, there is a considerable set of tabulations and accounts and listing and linkage routines, which will be listed under "computer simulations".

These six models will be linked in various ways to insure that changes in any one will affect others realisticly, and that they will present combined effects to the gamed decision roles and respond to decisions made by players in those roles. These internal linkages are the most difficult part of building the computer-simulated environment, and the required linkages to the gamed decision roles make the task even more difficult. Past experience in construction of gaming-simulations suggests that it will prove impossible to work out all the links that are initially intended while still others will become evident and be completed. This does not mean that the first version will not be workable and adequate for its purpose. But it does mean that improvements can be expected beyond the first version, primarily in the form of the working out of ways to build in more complex linkages. But it also means that some of those links may never get built in.

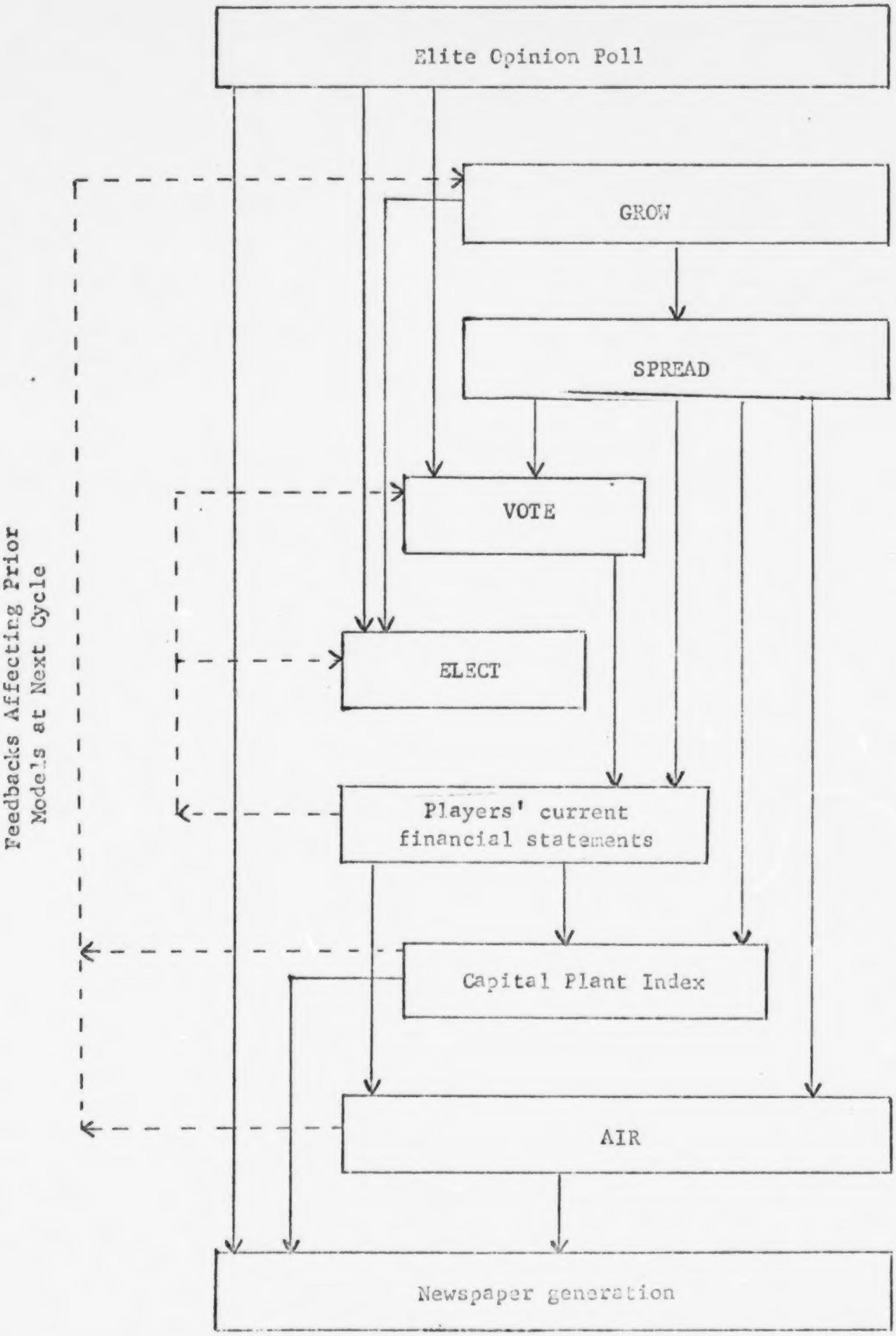
The GROW model deals with shifts in exogenously-generated employment, built-in basically as specified assumptions about growth rates of basic employment firms, representing the effect of national economic trends; it also includes increases induced by specific new firms (exo-firms) coming into the metropolitan area, on the basis of inducements by gamed decision roles (which they can choose to offer or not, and which enter into the decision by the exofirm about which specific location it will choose within the metropolitan area). Game operators can alter the major dimensions of employment change, including decline as well as growth. (See "Computer Simulations" for a more detailed description.)

The SPREAD model (a modification of T.O.M.M.) works primarily to distribute the new growth **spatially** throughout the various parts of the metropolitan area, so it is what is commonly called a "distribution model." SPREAD also takes the overall metropolitan growth from GROW and generates the additional employment and households (which demand housing, commercial areas, and public services and facilities), determining several rounds of secondary effects from the basic growth in employment. SPREAD spreads this growth to sections (analysis areas) of the community on the basis of physical accessibility and constraints of available land. The number of households of each particular type in each section are then determined on the basis of the level of public facilities, the types of households already there, and the available land in appropriate categories.

Thus, SPREAD balances shifts in positive and negative potential for growth of each analysis area against overall changes in numbers of households, operating withing the constraints. Where "spillovers" occur, when potential of an analysis area exceeds constraints, SPREAD operates to spread growth to the nearest appropriate adjacent analysis area. Thus, SPREAD operates to spread both new employment and new households to various sections of the community, to achieve an acceptable equilibrium of overall growth, as well as to reallocate some portion of existing employment or households. Output from SPREAD ovviously affects

Figure 8

APEX SIMULATED ENVIRONMENT


Elite Opinion Poll
GROW
SPREAD
VOTE
ELECT
Players' current financial statements
Capital Plant Index
AIR
Newspaper generation
Feedbacks Affecting Prior Models at Next Cycle

all of the following models, plus the capital plant indices (new population leading to new per capita indices), the school-age population, the issues that come into the gamed decision roles, and so on. (See "Computer Simulations" for a more detailed description.)

SELL is the real estate market model which processes the bids and offerings of gamed developers. As they bid for land, build homes and businesses, then offer these for sale, SELL measures these up against the increased demand generated by GROW and distributed by SPREAD. For residential land and housing, SELL determines whether or not there is a demand for housing in those analysis areas where a developer has chosen to build and offer homes for sale. SELL generates and records the selling prices for each type of housing and reports those sales which are completed for each developer. SELL also then makes appropriate adjustments in the tax assessment values for each analysis area. SELL operates in a similar fashion for the commercial and industrial real estate market. (See "Computer Simulations" for a more detailed description.)

The Voters' Response Model (VOTE) is a simulation of the electorate of the metropolitan area and its response to local government bond issues and millage referenca. VOTE is also used to process some other issues which might be subjected to referendum, such as an open housing ordinance, VOTE is based on household types, assuming that each type will vote in certain ways on different kinds of issues. (VOTE was calibrated on the basis of empirical data on voting histories in the Lansing metropolitan area.) The major VOTE variables are the percentage of eligible voters going to the polls on a given issue and the percentage of those actual voters who cast ballots favoring the specific issue. Since the numbers of households of different types in different areas is affected by SPREAD, the actual voting response will shift during the APEX gaming simulation, reflecting changes in the household characteristics of different analysis areas. Also the decisions about capital facilities and millages generated by VOTE will influence the capital facilities and hence the growth potentials of various analysis areas, feeding back to affect household types and voting response in those areas. In addition, gamed politicians can affect voting response by their decisions on capital facilities and also by the possibilities of spending campaign funds which may affect the voting on some specific issue, simulating the effects of publicity and voter education programs. (See "Computer Simulations".)

The Candidate Election Model (ELECT) must take into account and respond to some of the details of decisions made by gamed politicians, so it is necessarily a more complex model. Elections are assumed to occur every two cycles, so that ELECT must record and store a number of different decisions by each gamed politician across two cycles of APEX, in order to produce a simulated combined response of the electorate of a politician's jurisdiction to his performance since the last election. Voting response for ELECT is also based on household types and pressure groups and their assumed response to various kinds of decisions made by politicians. And again, politicians affect their election possibilities by spending money on political campaigns. (See "Computer Simulations".)

The AIR model simulates the general characteristics of the air mass over the metropolitan area, the emission of contaminants, and the accumulation of specific contaminants in the air over the separate analysis areas. AIR will include the generation of varying winds, temperatures, humidity, sunlight, inversion levels on a daily basis, but will report these only on a quarterly basis (these will include monthly, weekly and/ or daily data showing maximum concentrations, if it proves possible to make these shorter interval reports workable within the overall gaming simulation framework). These general weather variables will modify the distributions of contaminants across the metropolitan area. AIR will also include the generation or emission of specific contaminants (dust, particulate matter, nitrogen oxides, sulfur dioxide, carbon monoxide, hydrocarbons, and ozone) from uniform, line and point sources within the metropolitan area, and it will include residual contaminants carried in from outside the area. Contaminants from specific industrial, apartment, and public sources considered to be operated by gamed players will be reported, varying to some extent with levels of operation determined by gamed decision makers and with specific contaminant abatement measures exercised by them. General contaminant emission from traffic in each analysis area and from major traffic arteries and expressways will be included, as well as general contaminants from fuel combustion for all kinds of heating throughout the area. Data on contaminant levels will be reported out to gamed decision makers only for those analysis areas where monitoring stations are installed, but will be generated for all areas (allowing the number of monitoring stations to be increased by player actions). Possible spot inspection possibilities will also be included. (See "Computer Simulations".)

GAMED DECISION ROLES

There are five basic gamed decision role types in APEX: Politicians, Manager, Air Pollution Control Officer, Industrialist, and Developer. Politicians are differentiated by Central City and County governments, as are Managers. There are other minor variations which will be described under each specific role. Basically, the decision roles have the configuration shown in Figure 9.

The flexibility provided by having just five basic roles makes it possible to operate APEX with as few as nine players (a bare minimum) or up to 61 players (a maximum). The ideal number is 27, and it is assumed that at least 15 will be available for any runs at the Air Pollution Control Institute. The suggested role assignments for various groups is shown in Figure 10.

Role	Bare Minimum	Minimum	Ideal	Maximum
City Politician	1	1	3*	3*
County Politician	3	5	7	7
City Manager	1	1	1	3*
County Manager	1	1	1	3*
County APCO	1	1	3*	3*
Industrialists	2	4	7	21*
Developers	0	2	7	21*
Total	9	15	29	61

* The role is played by a team of players.

The following brief descriptions of each major APEX gamed decision role give the general rationale and general activities for each role during a cycle of APEX. (For a detailed listing of specific decisions for each role and the computer output information provided to each role, see "Gaming-Computer Links".)

FIGURE 9

Public Sector	Central City	County
Politicians	City Councilman	County Commissioners (also Health Commissioners)
Manager	City Manager (also Planner)	County Manager (also Planner and Health Dir.)
Air Pollution Control Officer		County APCO
Private Sector		
Industrialists	Determined by plant location(s)	
Developers	Determined by land holdings	

POLITICIAN

Each Politician, whether Central City or County, is elected by a specific constituency but serves as a member of the larger legislative body of his local government. Thus, Central City Politicians are elected from the three city wards, while County Politicians are elected from the Central City and the five simulated municipalities. Politicians are concerned with the effective and efficient operation of their governments in meeting the demands of metropolitan growth, but each is also concerned with pleasing his own constituents so as to increase his chances of being re-elected.

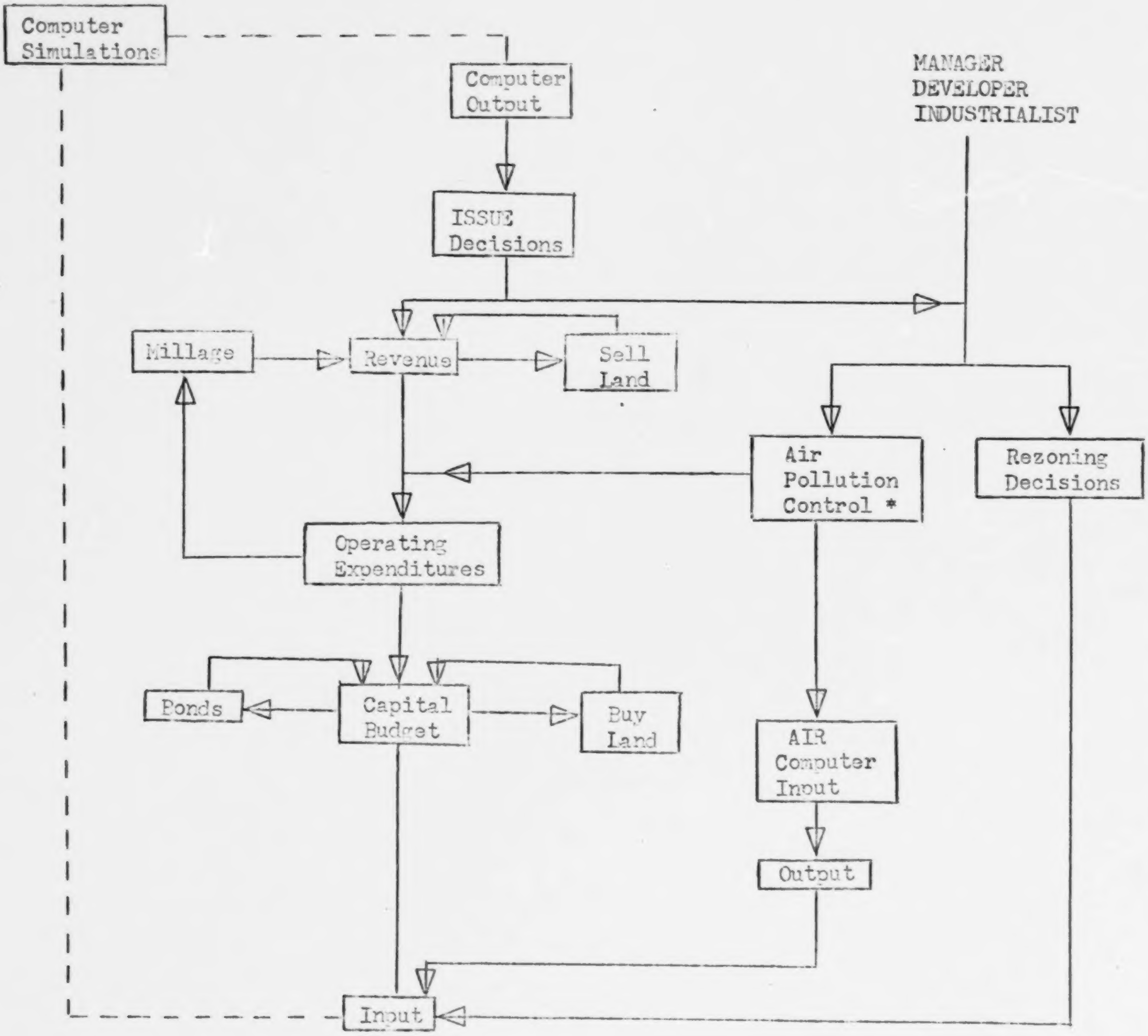
Politicians make the ultimate governmental decisions on routine matters, which must be dealt with every cycle, and on special issues and problems which may arise irregularly. They must make these decisions in interaction with, and often under pressures from, all of the other roles. The full list of general types of decisions is shown in Figure 11.

The most critical regular decisions, made every cycle, are those dealing with the generation of revenues and the expenditures of funds for goods, service and capital facilities. The chief source of local revenues in APEX is the general property tax, which may be supplemented by grants and rebates from state and federal governments, as well as by some revenues from collection of fees, licenses, fines, and service charges. Primary reliance on the property tax means that Politicians are vitally concerned with economic growth, especially that kind of growth which increases property tax assessments in their jurisdictions.

The Politicians rely heavily on the issuance of general obligation bonds for financing capital improvements. But their ability to issue these bonds depends upon approval by their electorates in bond issue referenda. These referenda are also a principal means for each Politician

Figure 11

POLITICIAN'S DECISION FLOW


Computer Simulations
Computer Output
MANAGER
DEVELOPER
INDUSTRIALIST
ISSUE Decisions
Millage
Revenue
Sell Land
Air Pollution Control *
Rezoning Decisions
Operating Expenditures
Bonds
Capital Budget
Buy Land
AIR Computer Input
Output
Input

* County Only

to determine how his performance is being judged by his own constituents, in his own voting area.

The politicians deal with both operating expenditures (for provision of basic services) and capital expenditures (for provision of major public facilities). Decisions about the operating budget are particularly relevant to the efficient and effective provision of services, while the capital budget is most directly related to opportunities for inducing growth or for meeting the needs generated by growth that occurs without inducement. In his capital budget the Politician makes decisions with far-reaching consequences. Different constituent groups vie with each other over the allocation of scarce funds to many needed projects, in many parts of the city or county. Residents of older areas, where facilities are obsolescent and need repair or replacement, compete with residents of newer areas (often allied with real estates and industrial interests), which need new facilities where none have existed before. (Many of these kinds of conflicting-interest problems will be raised for the Politician by headlines in the newspaper.) Before they can make their decisions on their capital budget, the Politicians must weigh the many alternatives (and each of them will be torn between overall concern for city or county and specific concern for the area which elects him).

The Politicians receive information as computer output from the simulated metropolitan environment which can assist them in making decisions on both issues and budgets. They get information about the socio-economic characteristics of their constituent households, reactions to their previous decisions, and economic activities in city or county, as well as the records of their previous years' decisions. They will also have various kinds of mapped and printed materials available in the simulation room, giving background about their jurisdiction, its history, its problems, and its trends. They can also consult with other players, especially the city or county Manager, who is considered to be appointed by them to carry on the affairs of the city or county.

The Central City Politicians and County Politicians play virtually the same role with respect to their fiscal decisions. But the County Politicians have the major role in public health and air pollution control, acting also as the County Health Commission. The County budgets will include both health and welfare expenditures for the entire metropolitan area, including the central city. City Politicians have their hands full with urban renewal, open housing, and other problems more germane to a densely-built-up city.

Politicians of both city and county take the final actions on planning and zoning matters within their jurisdiction, with the advise of their Managers. Managers are also expected to assist their Politicians on all other regular and irregular problems, issues, and decisions.

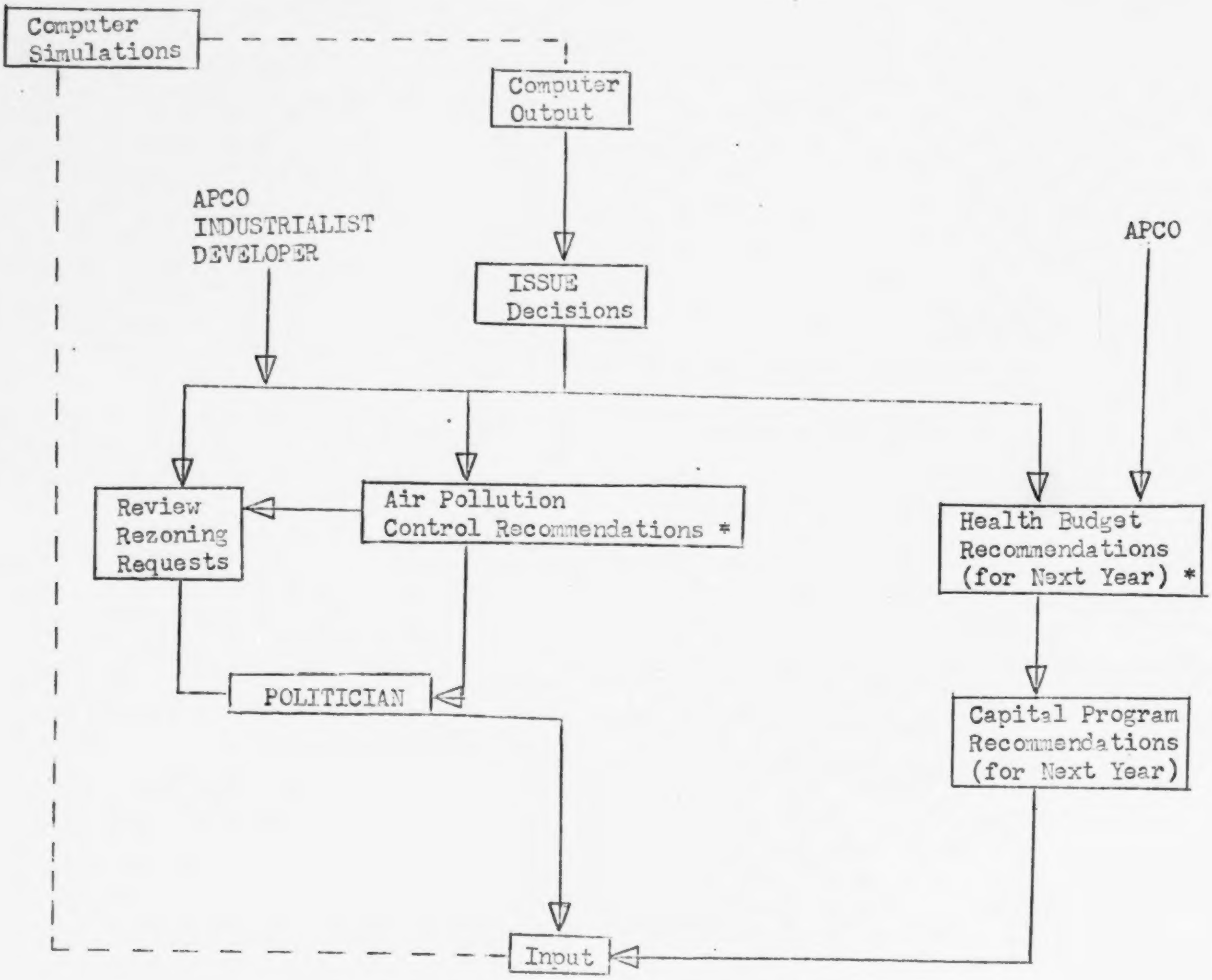
For the County Politicians, special information will be provided each cycle, representing the situation in the simulated municipality (and school board) from which each is elected. This information combines data on land use and zoning with a financial statement, a capital plant table with capital plant index, and some social indicators. County Commissioners representing the Central City will get such information from City Politicians.

MANAGER

Both the City Manager and the County Manager play composite roles in APEX. They combine the roles of chief administrative officer with those of planner and budget officer. They are thus responsible for

Figure 12

MANAGER'S DECISION FLOW


Computer Simulations
Computer Output
APCO INDUSTRIALIST DEVELOPER
ISSUE Decisions
APCO
Review Rezoning Requests
Air Pollution Control Recommendations *
Health Budget Recommendations (for Next Year) *
POLITICIAN
Capital Program Recommendations (for Next Year)
Input

* County Only

formulating an overall development plan for the growth of their areas and for trying to get this plan carried out through persuasion of Politicians, Industrialists, and Developers. The County Manager also serves as Health Director, which gives him primary responsibility for the air pollution control program, as will be discussed in more detail below.

The Manager is staff to the Politician, so he can only decide to make recommendations for final decision by the Politicians, Thus, the primary tools the Manager can use to influence growth and development are his recommendations on zoning, on admission of exofirms, on operating budget, and on the capital improvement program. He may try to convince the Politicians to rezone land to conform with his proposed development plan, or he may try to get them to refuse to rezone the land as requested by a Developer or Industrialist. The general set of decisions is shown in Figure 12.

The Manager works one year ahead and thinks even further ahead in preparing his capital budget for annual submission to his Politicians. He must compete for attention with the short-run concerns and time constraints which the Politician faces, so he will usually find it difficult to get Politicians to worry about the capital budget he is preparing to help them in next year's decisions. And his concentration on next year may be drawn off by the Politicians requests that he help them decide on this years' budget or that he handle some brush-fire emergency situation. But the Manager will be concerned about those current budget decisions, so he will be prepared to counteract the pressures which other players will put on the Politicians, to get their pet projects included. The Manager may also find time to point out information which the Politicians have not seen or have not considered relevant, such as specific headlines in the newspaper pointing toward problems which may get worse if not handled immediately.

As County Health Director, the County Manager is responsible for the health section of the annual budget, including both operating and capital expenditures (such as hospitals). He must consolidate the budget requests of the Air Pollution Control Officer into the health budget, and the health budget into the overall county budger, which is being decided upon by the Politicians. These current budget decisions will determine how much funds are available for health and air pollution control in the next cycle, so both Health Director (County Manager) and APCO will be vitally concerned. Thus, the Health Director will work closely with the APCO in working out an air pollution control budget, in the light of realistic estimates of probable revenues and other demands for funds.

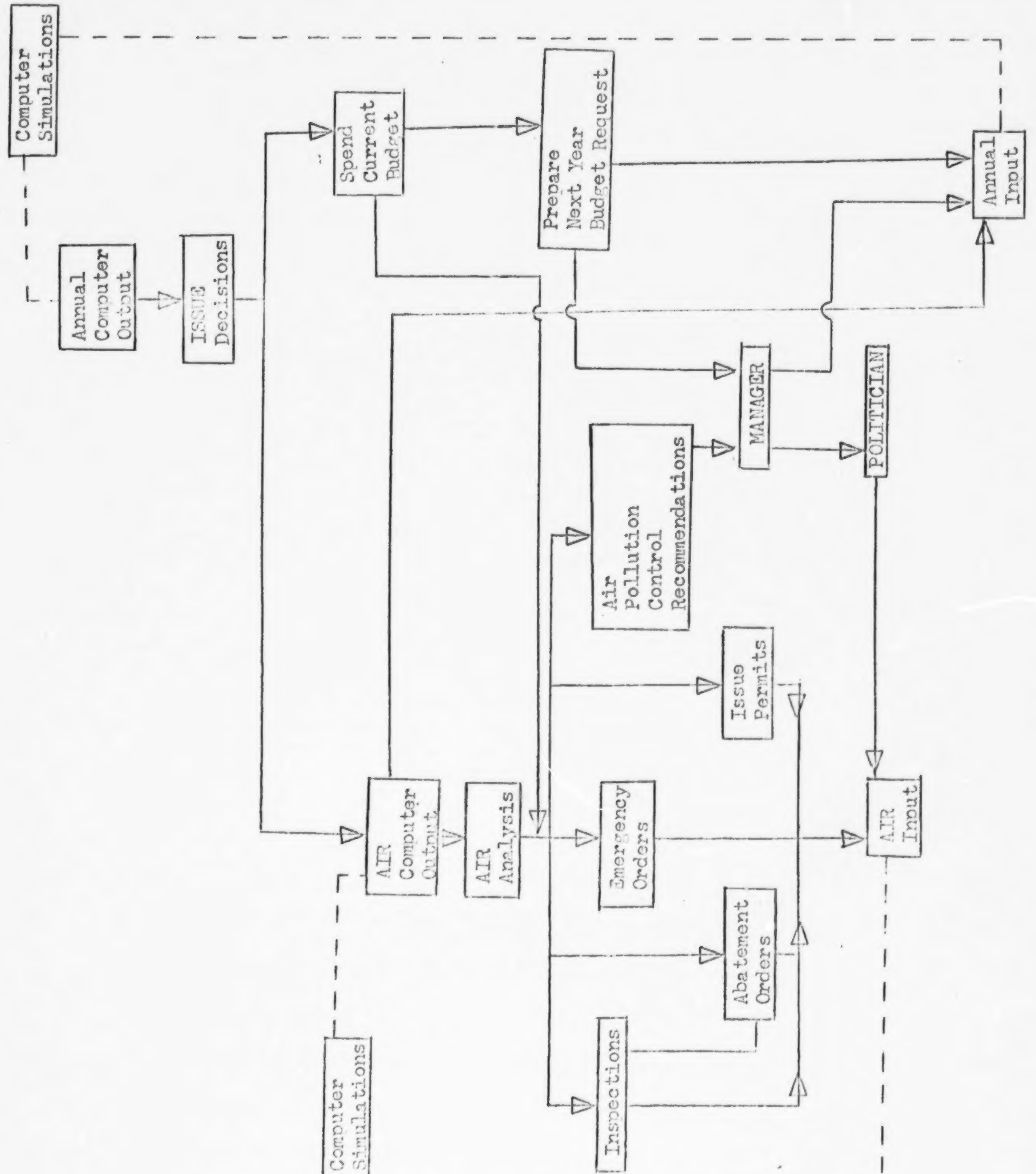
The City Manager and County Manager will both have a variety of information to aid them in making their recommendations and decisions, including computer output from the previous cycle, wall charts and other materials in the simulated room (described more fully in "Player Preparation and Support Materials"). They will also accumulate information about how their Politicians have acted in the past and what pressures are being brought to bear on the crucial fiscal decisions. Beyond this, the role is flexible, permitting each player to shape his own strategies for gaining information and using it to influence others.

AIR POLLUTION CONTROL OFFICER (APCO)

The Air Pollution Control Officer's major concern is the maintenance of air quality throughout the metropolitan area. He obviously shares this concern, and the responsibility for accomplishing it, with the County Manager and County Politicians, and with other players. But he is assigned the primary responsibility for maintenance of air quality by monitoring, investing, and regulating air contaminant

Figure 13

APCO'S DECISION FLOW


Computer Simulations
Annual Computer Output
ISSUE Decisions
Spend Current Budget
Prepare Next Year Budget Request
Annual Input
MANAGER
POLITICIAN
Air Pollution Control Recommendations
Issue Permits
AIR Computer Output
AIR Analysis
Emergency Orders
AIR Input
Abatement Orders
Inspections
Computer Simulations

sources, proposing standards and regulations to deal with particular contaminants and particular areas of the County, and for enforcing established air pollution control regulations and laws by persuasion or by initiating legal action.

To accomplish these objectives, the APCO must work closely with both the County Manager and the County Politicians, to assure that he has the necessary funds for current operations and future program expansion. He will work with them for the passage of laws and regulations and approval of his long-range air pollution control program. He is dependent on their action for approval of his budget requests so that he can install the necessary monitoring stations to get air data and to pay for the special inspections he needs to make to determine which source is causing illegal contaminant levels in some part of the county. He will continually be forced to modify his plans as a result of the fiscal and political realities which the Manager and Politicians must deal with. And he will usually have to compete with them for time to settle urgent air pollution issues and problems. Figure 13 lists the chief decisions which the APCO may make during a cycle.

The APCO works on a quarterly cycle for his air pollution control activities, as well as on an annual cycle for his budgeting activities. He receives information about air characteristics and contaminant levels on this quarterly basis, but only from those sections of the metropolitan area where he has already installed monitoring stations. He can spend previously budgeted funds (decided last year) for inspections of specific sources which he believes are emitting contaminants. He can issue statement orders in these quarterly periods, requiring industrialists to alter their operations to reduce contaminant emissions below legal levels. In emergency situations he can act to close down industrial operations, trash burning, or even auto and truck traffic, provided these have been established as legal pollution control actions by County Politicians.

The APCO is responsible for making his findings about air contamination known to the public-at-large and to the County Health Director and Politicians. Of course, this information becomes his chief weapon as he makes and defends his requests for operating funds and for new or altered regulations and air quality standards. He may also spend some funds on public education and information, if that is necessary to get compliance on the abatement of such general contaminant sources as trash burning and domestic heating.

When the APCO prepares his budget requests, these will be his estimates of the funds he will require during the next cycle or year. This means that he must make some estimate of the amounts required for installation of additional air monitoring stations in parts of the metropolitan area not now covered or to measure levels of contaminants not now measured. And it also means that he will need to estimate how many special spot inspections he will need the following year, since when that year arrives he can only make as many as his approved budget allows him to pay for.

In the midst of all these activities, the APCO is also concerned with developing some long-range program for monitoring and regulating air contamination. He will find it difficult to make time for this in his busy schedule in APEX, but it will be essential for him to devote some time to it and to getting general approval of his overall strategy by the Health Director and County Politicians, (For this purpose it may be desirable to have one or more special decision exercises, like MAPCORE, devoted to the development of such a long-range air pollution control program for the APEX community.)

INDUSTRIALIST

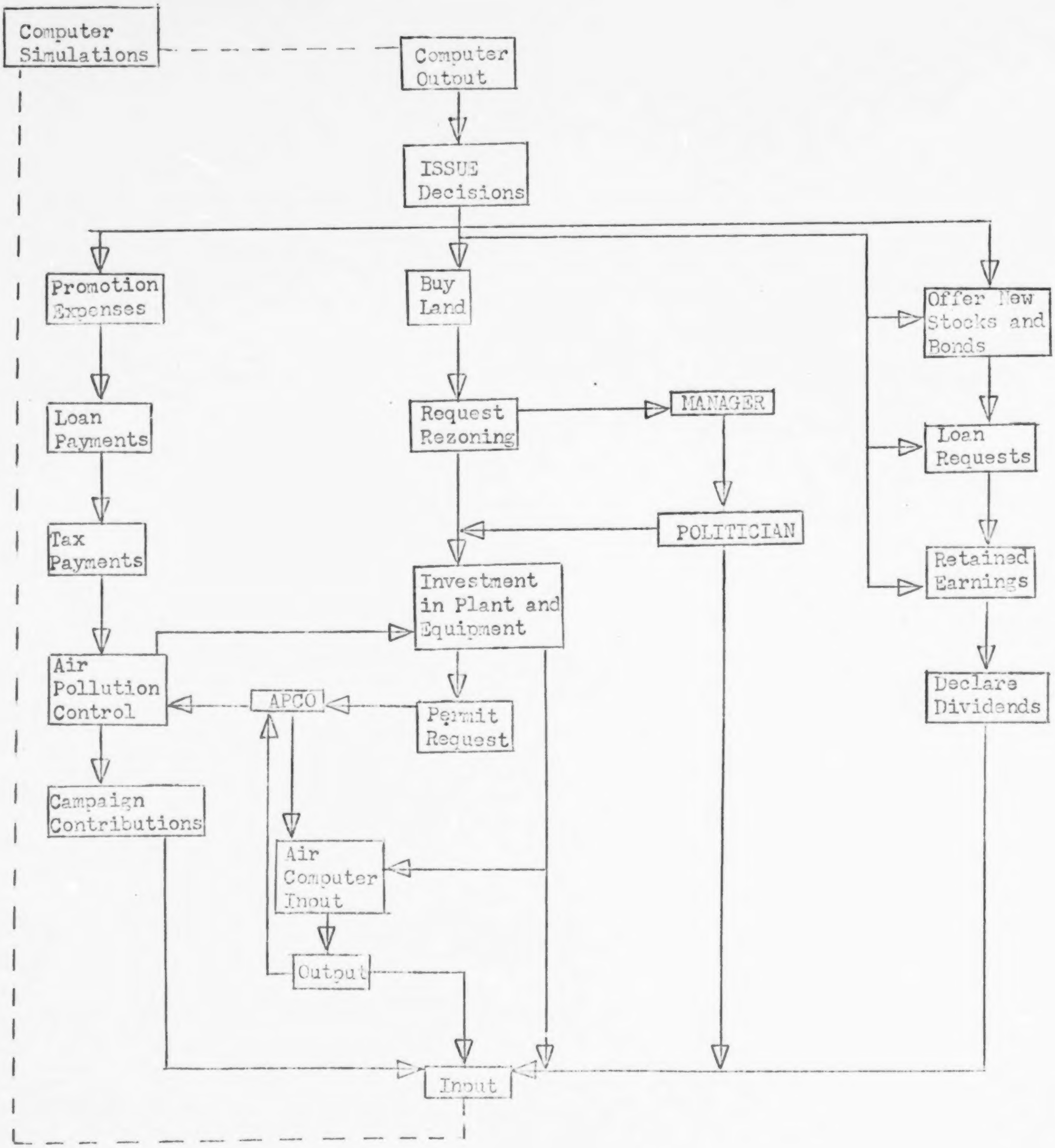
Gamed Industrialists are considered to be managers of industrial plants located at specific points in the metropolitan area. Each Industrialist represents just one firm, but he may have plants at more than one location (and perhaps even plants of more than one type). Each gamed Industrialist will start with one or more fixed plants, but he may also add new plants during the APEX cycles (perhaps even taking a new exofirm). The Industrialist will also reside in some particular part of the metropolitan area, so that he may have conflicting interests between his industrial operations and his living conditions.

APEX will have seven major types of gamed Industrialists, though not all will be included when there is a minimum number of players. Thus, Industrialists may represent a power plant (considered to also serve Michigan State University), an oil refinery, a cement plant, a dry cleaning operation (probably with several locations), a chemical plant, a steel plant, and a property management firm (operating large apartment and office buildings). Each of these represents a major air contaminant generator. A large manufacturing plant may also be included, representing the gaming of one of the three major employers (Oldsmobile) which is also a contaminant generator and is a division of a larger outside industrial firm.

Each Industrialist will have the same general set of decisions and activities, with variations determined by differences in land requirements, market orientations, location of management control, and air contaminants. All gamed Industries are assumed to be large operations, with large employment, plant, land area, and tax assessment. Some

Figure 14

INDUSTRIALIST'S DECISION FLOW



Computer Simulations
Computer Output
ISSUE Decisions
Promotion Expenses
Buy Land
Offer New Stocks and Bonds
Loan Payments
Request Rezoning
MANAGER
Loan Requests
Tax Payments
POLITICIAN
Retained Earnings
Investment in Plant and Equipment
Air Pollution Control
APCO
Permit Request
Declare Dividends
Campaign Contributions
Air Computer Input
Output
Input

will have only a local market (power plant, dry cleaning, property management) so that they are under local control and their markets are determined by local economic conditions. Others will have external markets in various proportions, so that their demand is determinded exogenously to some degree, and some may be controlled from outside this metropolitan area.

Industrialists will have part of their attention focussed on their normal industrial and business operations. They will have to make annual decisions about employment and production levels, plant locations and expansions, capital equipment, and the loans, stock and bond issues, and dividends which accompany those operations. They will have to pay taxes in the jurisdictions in which they are located (so plants located in the central city will pay taxes to city and county and school board). They will be seeking to make profits and declare dividends from their industrial operations. See Figure 14 for decisions.

But each Industrialist will also have specific air contaminant emission characteristics associated with his industrial operations, varying with his level of operations and the types of equipment he installs. These characteristics will be available to the APCO as a result of investigation. If the Industrialist is found to generate excessive contaminants, above legal pollution levels, the APCO can order him to abate that pollution. Then the Industrialist must install adequate control equipment, change fuels, cut down on his level of operations, change his processing operations, or take some other measure which will decrease his emissions of contaminants. If he does not, he can be taken to court and forced to comply. He can also appeal any order of the APCO to an Air Pollution Appeals Board (MAPCORE exercise) or even from their decision to the courts (a MAPCORE moot court).

The County Politicians can also approve a recommendation of the APCO to set up a permit program, requiring that Industrialists obtain permits for their contaminant emitting operations and for control equipment installations.

The Industrialist can conform to APCO orders to abate by actions taken during the quarterly cycles of the AIR model, except where major equipment installation is required. In that case, such capital expenditures will be taken up in the annual capital decisions of the Industrialist, and there may even be some lagged effects representing the time it takes to install some kinds of equipment. However, the Industrialist can comply with fuel change orders (if that equipment is already installed) and with orders to shut down operations in emergencies, on a quarterly basis. These quarterly decisions of the Industrialist will be reflected in immediate changes in the AIR model (next quarterly output).

The Industrialist may choose to exert pressure on the County Politicians to take actions which will further his economic goals, whether those deal with general growth which affects his markets or with air pollution control requirements which cost him money. He may also request rezoning when that will permit him to expand an existing plant or to start a new one, and he may request city or county capital expenditures to aid his expansion (as for exofirms). The Industrialist may generally work through the County and City Managers, but they may also go directly to the Politicians. He may lobby against proposed air pollution control ordinances and air quality standards, and against specific annual budgets for air pollution control. He may try to get the County Manager or County Politicians to keep the APCO from enforcing pollution standards against him.

The Industrialist will have the same general information available to him that has been discussed for other players, including all the data available in the simulation room. In addition, he will have specific computer output with records describing the status of his industrial and financial operations. He can get AIR characteristics data on a quarterly basis from the APCO, or perhaps even buy it himself directly from the operator. He may also join with other Industrialists and Developers to pool information about the local economy.

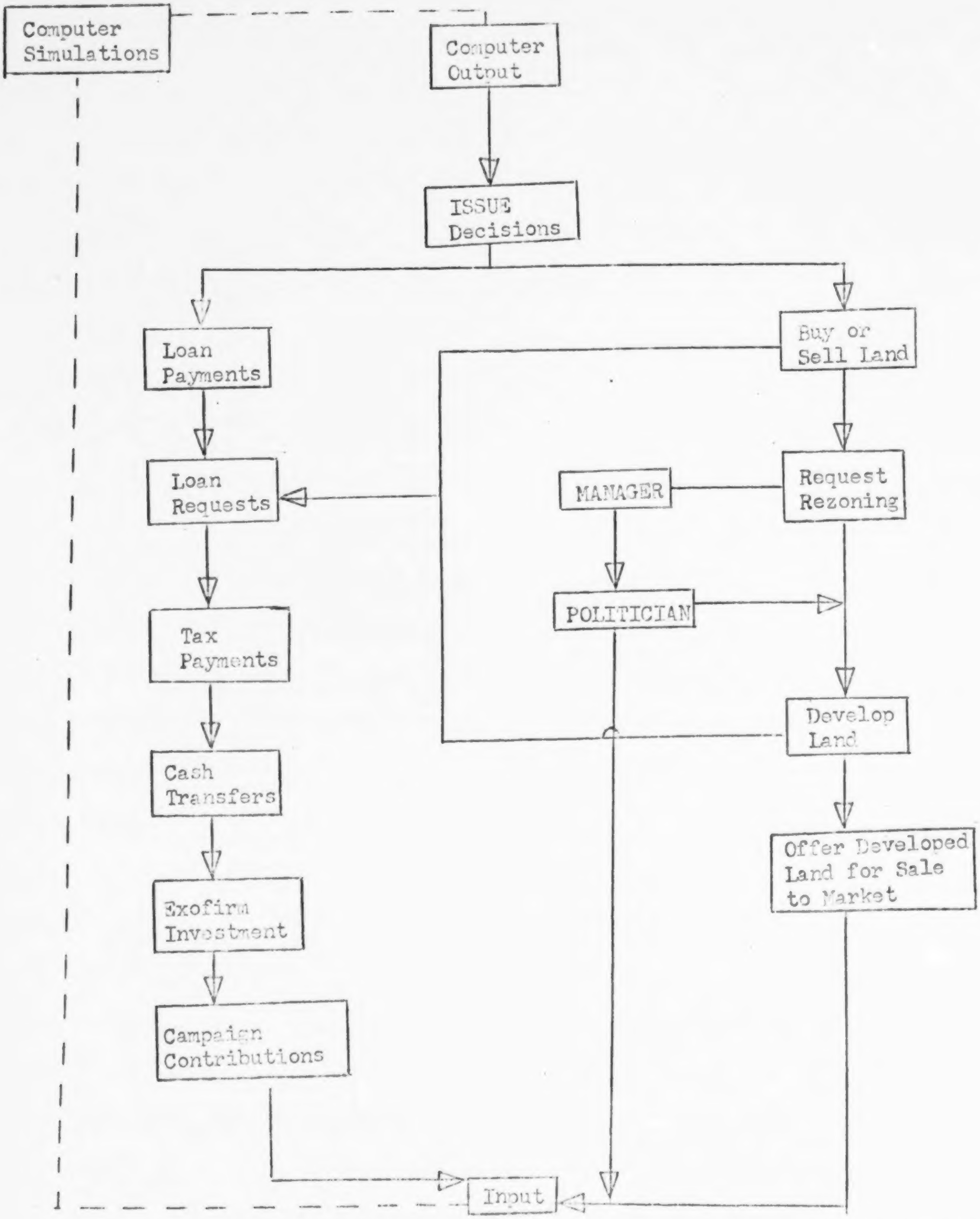
DEVELOPER

For the gamed Developers, the primary goal is to make profits through the purchase, development, and sale of residential, commercial, and industrial property. They make decisions about buying and selling land, in transactions both with other gamed roles and with the simulated real estate market. They may request rezoning of land by Politicians in order to be able to build the type of units for which they estimate there is a market. They speculate on growth that might occur in various areas of the Central City and County, so they will be involved in trying to get Politicians to provide services and facilities that can induce growth in those specific areas. They will be concerned with industrial expansion or location by gamed Industrialists or the possibilities of new exofirms coming in, since those will also enhance the values of land and development in specific sections of the metropolitan area. The general set of Developer decisions is shown in Figure 15.

The seven gamed Developers all make the same kinds of decisions but each has different financial resources. Each Developer may also choose to concentrate on different parts of the development market, in different sections of the community. Each Developer also resides in some specific location, so he will have personal interest in the development of his home area. This may bring him conflicting concepts, as when a

Figure 15

DEVELOPER'S DECISION FLOW


Computer Simulations
Computer Output
ISSUE Decisions
Loan Payments
Buy or Sell Land
Loan Requests
MANAGER
Request Rezoning
POLITICIAN
Tax Payments
Develop Land
Cash Transfers
Offer Developed Land for Sale to Market
Exofirm Investment
Campaign Contributions
Input

large manufacturing concern may enter into his home area, opening up opportunities for investment but also affecting his home living environment.

Developers also pay taxes on their vacant and developed land, with the scale depending upon their total holdings at the time of tax assessment. Thus, they are vitally concerned with Politicians' decisions about operating expenditures, capital expenditures, and tax rates. At the same time they are interested in getting such expenditures in those areas where they hold land. So Developers will tend to be continually pressuring Politicians to keep down total spending, "but don't forget those projects in my area."

Developers are not confined to any one portion of the metropolitan area for their business operations, although they can only vote on "Elite Opinion Poll" issues for the jurisdictions in which they reside. They start out with property in several areas, some vacant and some developed, and with all land in some zoning category. Then the individual Developer can decide whether to continue to operate in those initial areas or to spread out to others. He may sell some of his initial land to get capital for this purpose. He can also negotiate loans from players or operator.

Developers get special computer output recording their land holdings in various categories and their financial status. They have access to all the general computer printout information provided to all players , as well as to the general information available in the simulation room. They are free to try to obtain additional information from other players, either their own special computer output or information about their future intentions. Thus, Developers will be concerned with finding out ahead of time what the Managers propose as the locations for capital projects next year and whether or not the Politicians will act on those proposals, for this is one of their opportunities for profit from land speculation and development. More details on Developers' information is discussed under "Gaming-Computer Links".

PROBLEMS, DECISIONS, AND ISSUES

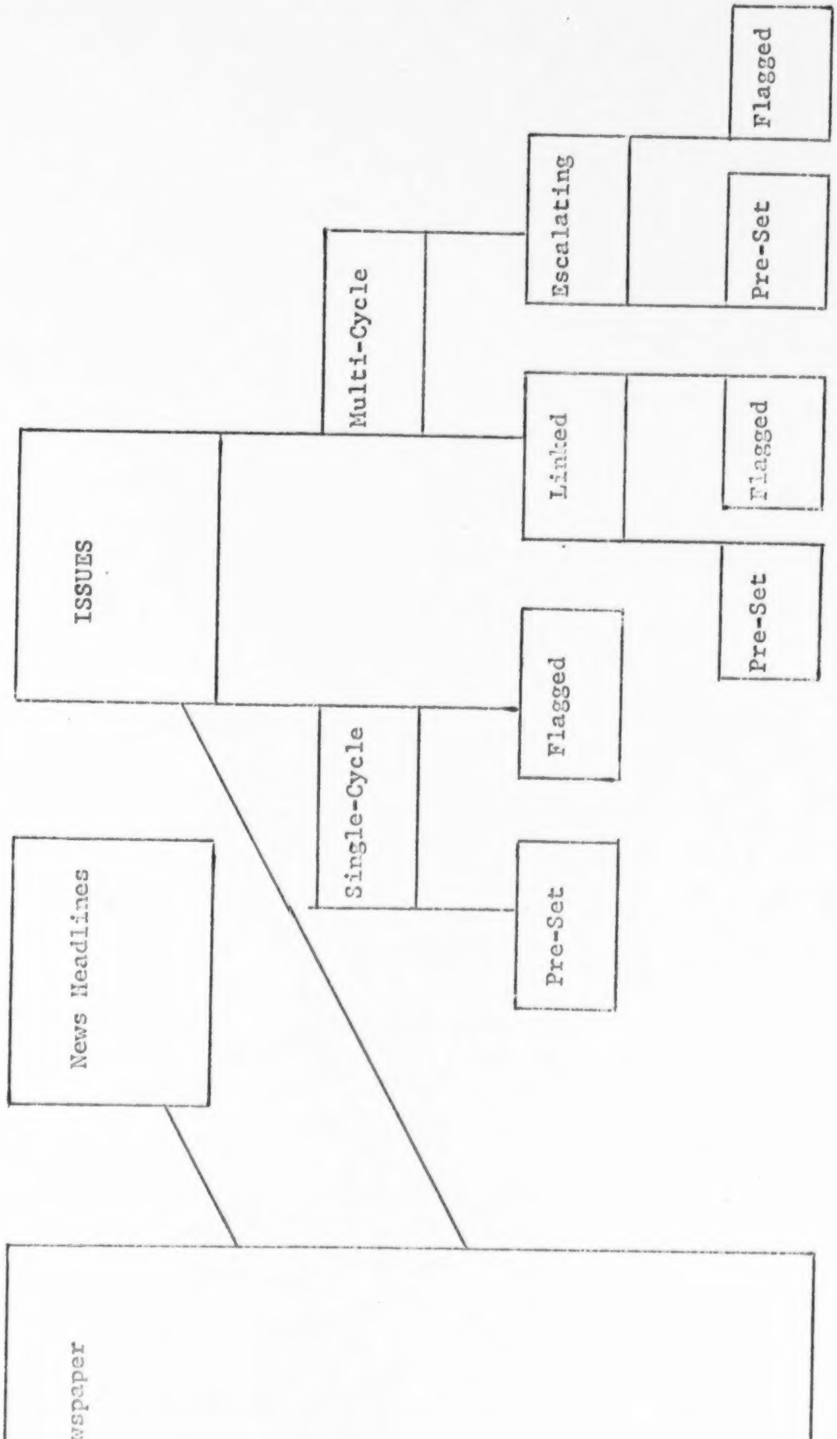
Gamed decision makers are faced with a considerable variety of problems, decisions and issues in the APEX gaming simulation. Since these terms are used with specific meanings in descriptions of APEX, and since there is a rich variety of possibilities for confronting players with situations requiring or permitting decision or resolution, it is important to describe these in some detail.

In general, problems in APEX can be viewed as situations in which some goal, objective, or decision criterian is not being satisfied. This can only be determined by comparing someone's goal, objective, or criterion against some measure of the actual situation to determine whether or not there is satisfaction or dissatisfaction. Thus, there may be problems for simulated households, industries, governments, or developers, but there may also be problems for gamed Politicians, Managers, APCO, Industrialists, or Developers. Some of these problems are preset, having been built into the game and being reported out to the gamed decision makers. Other problems will arise from goals, objectives, and decision criteria which players establish, as when legal air pollution standards are passed by County Politicians. And some problems are set for the players by various kinds of decisions which are required, (such as decisions on annual budgets). Thus, problems can be either programmed or unprogrammed in APEX (although generally they would not be programmed in the real world).

Decisions have some obvious relations to problems, but they are not the same. Some problems can suggest decisions, but not require them, so that real or gamed decision makers can avoid decision, refusing to resolve some problem at any given time - perhaps postponing or deferring action, perhaps never taking action and hoping the problem will go away - or that it was never really there. In most cases, however, pro-

Figure 16

ISSUE TYPES


Newspaper
News Headlines
ISSUES
Single-Cycle
Pre-Set
Flagged
Multi-Cycle
Linked
Pre-Set
Flagged
Escalating
Pre-Set
Flagged

blems seem to require some kind of decision, even if it is the decision not to do anything.

It may be useful to differentiate as well between those decisions which are explicit, such as a vote on a particular programmed issue, a decision on allocation of funds for some expenditure in the budget, or a decision to buy certain land, and those decisions which are implicit, not being clearly stated so that others can know it, such as some general policy or strategy to be followed in making whole sets of decisions. This suggests that it will be useful to differentiate between such policy decisions, intended as decision rules to apply to a set of later specific decisions, and the single-shot or spot decisions. Thus, implicit policy may be established by some player on the basis of a set or sequence of decisions made in the same way over time. Although he never makes that implicit policy clear, even to himself, other players may sense the general pattern and become aware of how he makes that kind of decision, taking this awareness into account in subsequent interactions.

Headlines in the APEX newspaper,generated as part of the computer output each cycle, may present problem s about which decision makers should be concerned (such as protests by local residents about flooded basements or trash burning). Such headlines do not require any action by the gamed decision roles, which clearly differentiates them from issues (as discussed below). Headlines may provide clues to issues which will arise at later cycles, which will then require decision, and failure to pay attention to headlines may affect politicians' election possibilities (ELECT).

APEX issues are presented to players in the newspaper in fixed form, with fixed alternatives requiring decision (action, no action, deferral). Players are required to turn in issue decision forms, casting their votes on these issues in an "Elite Opinion Poll", so that there is assumed to be no abstention. Some of these required issue decisions become binding on the ultimate decision makers, so that they require the Politicians' to act (as if this had been a referendum submitted to the voters). Other issues may be only advisory, with the Politicians deciding for themselves whether or not to pay any attention to the "elite," but also expecting that refusal to follow their advice may affect chances of re-election (ELECT). Binding and advisory issues are clearly differentiated in the newspaper.

Some issues are spot issues, occurring only in a single cycle and resulting in some immediate decision. Others are linked issues, with strings of two or three issues over several cycles in some logical sequence, representing the interdependencies between different kinds of problems. Others are escalating issues, building up a major theme over several cycles, with an unfolding, branching tree of developments, usually involving increasing severity of some general kind of problem. For such escalating issues, the decisions of players will lead off into branching paths, depending on the specific decisions they make at each "fork" or branching point. Some of these distinctions are shown in Figure 16.

Fixed issues are preset to occur in specific APEX cycles, while flagged issues will occur only in response to some situation which may arise in any cycle. Flagged issues establish a framework in which some of the key air pollution problems can be dealt with. Thus, there will be definite thresholds,for levels of various contaminants, will be flagged so as to trigger specific issues about air pollution. These thresholds must be understood as something quite different from legal air quality standards which players may establish. These air contamination thresholds, in effect, represent nature's air quality standards. But they must be built into the AIR model (or into some linkage with the rest of the simulation) so that air contamination problems will be raised for the gamed decision roles even if (or especially if) the players deliberately or inadvertently fail to act to establish and enforce air quality standards. Thus, some air contamination levels will pass these built-in thresholds and trigger flagged air pollution issues, unless the players have already established a similar standard. This approach can be used to deal with the kinds of contamination which is irritating but not dangerous, which can be sensed by people in the community so that they react to it (like eye irritation), but which may not necessarily require immediate action by the decision makers.

APEX includes a variety of issues, dealing with urban renewal, open housing, public housing, tax reassessment, capital projects, and so on. Some air pollution issues will also be included, especially those that can be considered to result from air contamination levels that affect people in some part of the metropolitan area but which are not being handled through the air pollution control program. But most air pollution problems will arise as specific decisions requiring action by gamed decision roles, and not as issues specifically reported in the newspaper.

All these are problems, decisions and issues which are built into APEX computer simulations and gamed decision roles. There will be other problems and decisions which will arise out of the interactions of decision makers. Thus, Politicians, Managers and Developers will interact on zoning issues, raising problems for each other to deal with. Or the possibility of some exofirm coming in will give rise to competition between city and county Politicians. Or Industrialists will find problems in their interactions with the APCO and county Politicians and

Manager over setting air quality standards or complying with those that are already set. Thus, there is a whole set of problems and decisions that is generally expected, in that general sense programmed into APEX, yet the specifics are completely unprogrammed, arising out of the personalities of the players almost as much as the situations they are forced into in the gaming simulation.

DECISION-CENTERED INTERACTIONS

Many of the interactions among gamed decision roles or between roles and the computer-simulated environment have already been discussed, hinted at, or implied. The complexities of interaction are so great that it is best to concentrate here on those which center on the most critical kinds of decisions faced by the players in APEX. These decision-centered interactions will include only the principal roles and simulation models which tend to interact in the making of key decisions.

For it is possible for each role to interact with each other role and each model about each key decision. In actuality, the gaming-simulation tends to separate into subsets, with several roles interacting with several models in the making of a key kind of decision. These subsets tend to focus on the decisions on issues, local public finances (revenues and expenditures), local public facilities (capital projects), private land and development, exofirm location, and air pollution control. These subsets overlap with the same roles and models in several subsets.

Although it is not feasible to show all interactions in one diagram, Figure 17 sets the stage for discussion here by showing all of the seven roles, six major models, five key decision types, eleven simulated municipalities and school boards, and some of the most significant interactions which can be indicated at this general level. Where interactions almost always occur, they are shown by solid lines (although in some cases they may not take place). Where interactions occur less often, but are significant at this level if they do, they are shown by dashed lines. All of the other possible interactions are not indicated on this diagram. Some of these will be shown on the separate decision-centered diagrams.

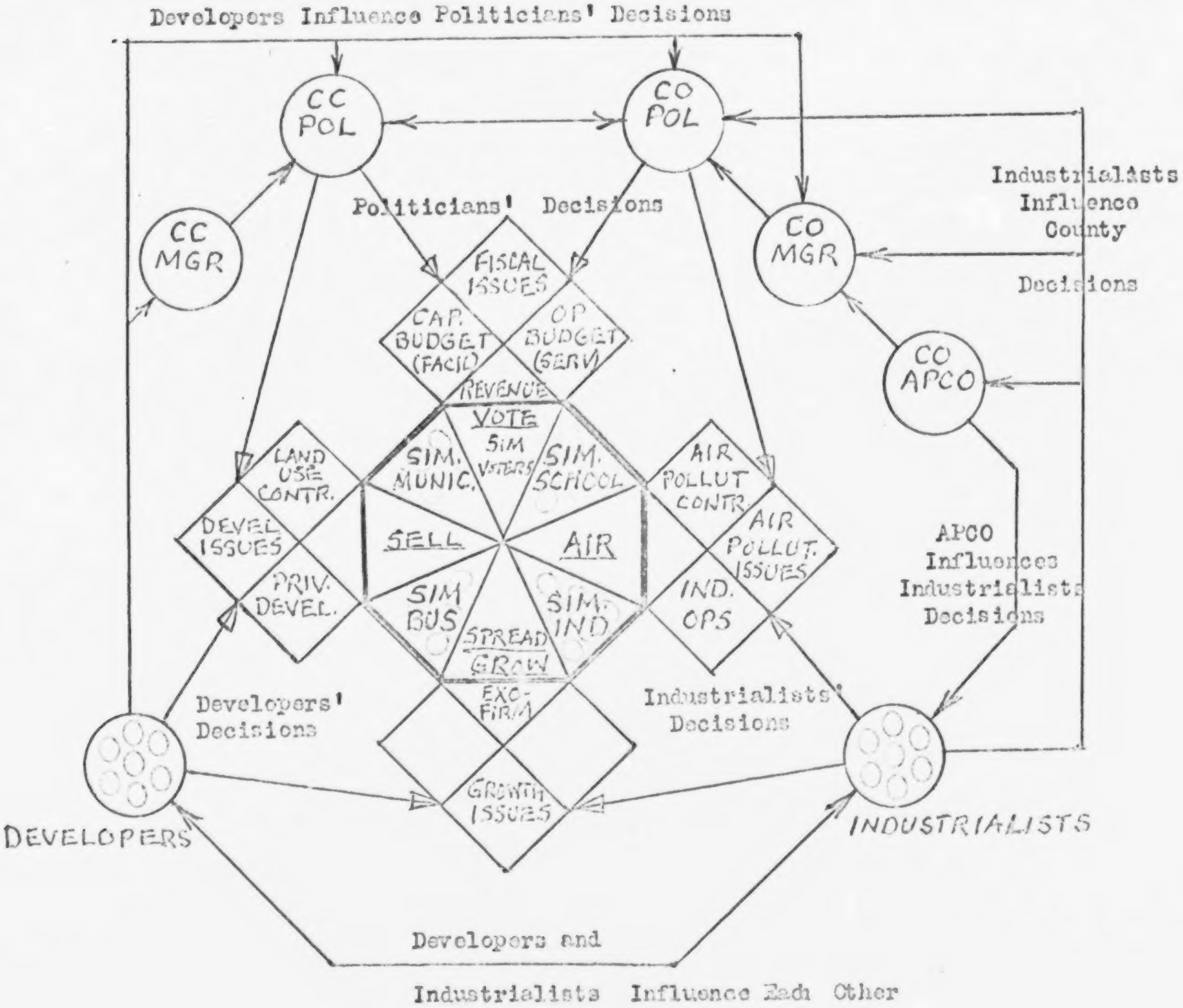

Developers Influence Politicians' Decisions
CC POL
CO POL
CC MGR
CO MGR
Politicians' Decisions
Industrialists Influence County Decisions
FISCAL ISSUES
CAP. BUDGET (FACIL)
OP BUDGET (SERV)
REVENUE
VOTE
SIM VOTERS
SIM. MUNIC.
SIM. SCHOOL
SELL
AIR
SIM BUS
SIM. IND
SPREAD GROW
EXO-FIRM
LAND USE CONTR.
DEVEL ISSUES
PRIV. DEVEL.
AIR POLLUT CONTR
AIR POLLUT. ISSUES
IND. OPS
CO APCO
APCO Influences Industrialists Decisions
Developers' Decisions
Industrialists' Decisions
GROWTH ISSUES
DEVELOPERS
INDUSTRIALISTS
Developers and Industrialists Influence Each Other

Figure 17

APEX GENERAL INTERACTION DIAGRAM

General Issues

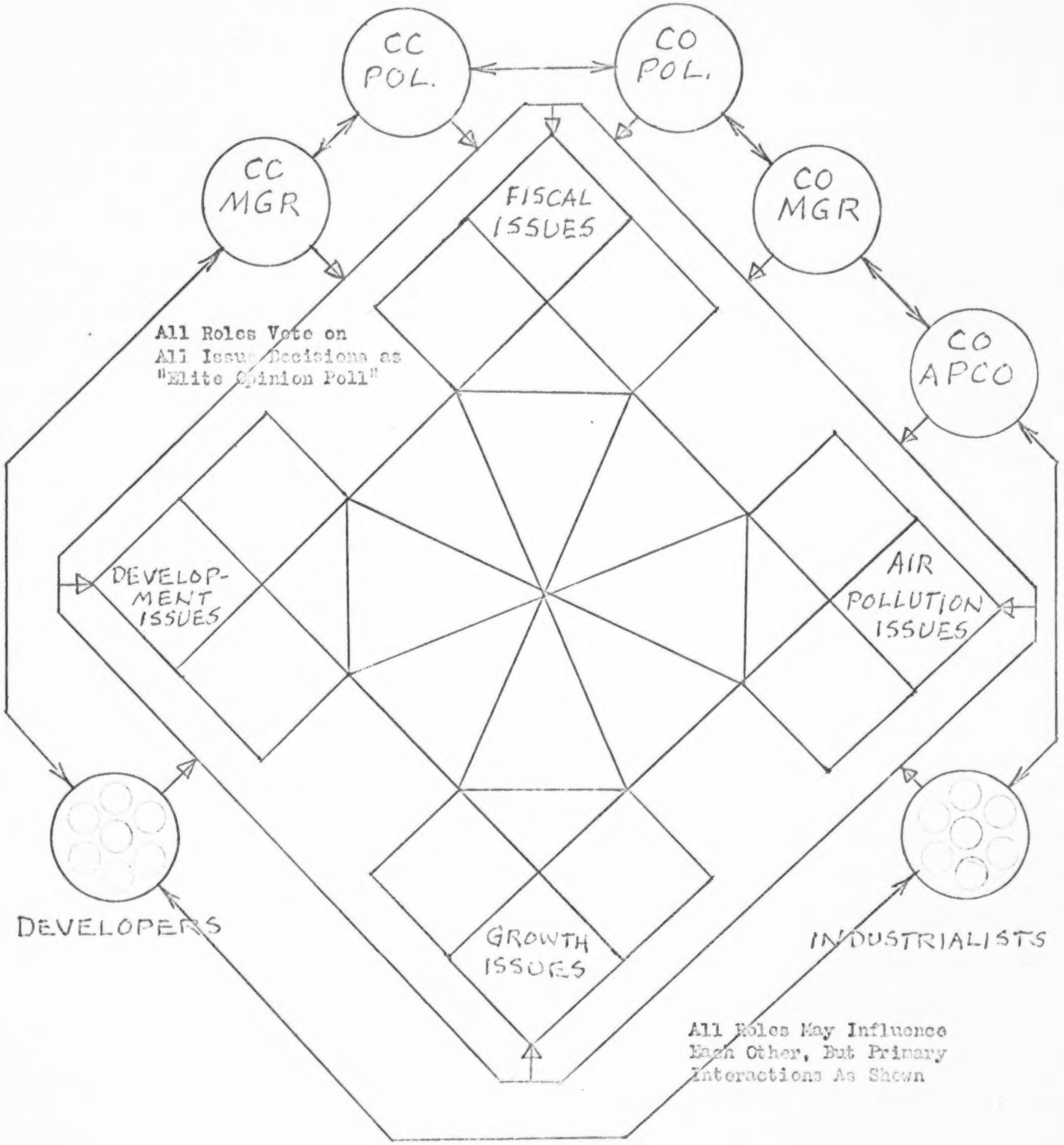
Since all gamed roles are expected to fill out decision forms on those issues which are specifically listed in the newspaper, they all interact with issue decisions. Issue decision forms are turned into the gaming operator and tabulated for computer processing. Then they provide inputs to the VOTE and ELECT models and to the newspaper generator. Single-cycle (spot) issues do not lead to any further newspaper items, but linked issues and escalating issues do, and these become inputs for the roles at the next cycle. Thus, the issue-decision-centered interactions can be diagrammed rather simply as shown in Figure 18.

Local Public Finances

Decisions about local public revenues and expenditures involve a considerably more complex set of interactions. All gamed roles are, or may be, involved, since they all are concerned with either the expenditures of funds for things that will help them satisfy their own goals or with the revenues which will require their payment of taxes. Central City and County Politicians, the simulated municipalities and school boards, and the simulated electorate (VOTE) will make the decisions, while both Managers, the APCO, the Industrialists, and the Developers will try to influence those decisions. Three of the major models will also influence local public revenues or expenditures fairly directly, while the others will have indirect effects over several cycles. GROW, SPREAD, and VOTE are the major models involved, but the major subroutines which calculate financial statements and capital plant indices, and generate the newspaper are also included. Managers and APCO are concerned with both the current budget (next years' expenditures) and

Figure 18

GENERAL ISSUES INTERACTIONS


CC POL.
CO POL.
CC MGR
CO MGR
CO APCO
FISCAL ISSUES
DEVELOPMENT ISSUES
AIR POLLUTION ISSUES
GROWTH ISSUES
DEVELOPERS
INDUSTRIALISTS

All Roles Vote on All Issue Decisions as "Elite Opinion Poll"

All Roles May Influence Each Other, But Primary Interactions As Shown proposed budgets for next year (the following years' expenditures), which are also included. (See Figure 19.)

Local Public Facilities

Decisions on schools, streets, parks, sewers, water main, hospitals, and other local public facilities are also made by the Central City and County Politicians, the simulated municipalities and school boards, and the simulated electorate (VOTE). All the other gamed roles may also be involved through their special interests. Here the major models involved are GROW, SPREAD, and VOTE. Although roles and models are the same as for local public finances, breaking out capital facilities makes it possible to deal more specifically with some of the interactions, as shown in Figure 20. Here the calculation of capital plant indices and newspaper generation are also shown. Again, the Managers have part of their attention focussed on next years' capital budget, as their recommendations which the Politicians will consider next cycle. These public facility decisions involve not only specific capital projects in specific locations, but also the funds necessary to pay for those facilities, so routines for calculation of financial statements are also shown.

Private Land Development

Both the public and private sectors are involved in decisions about private land development, since the local governments place constraints on that development through zoning as well as stimulating or discouraging development in specific areas through their decisions about the provision of local public facilities and services. Developers and Industrialists are involved, along with Politicians, Managers, and APCO (the latter is primarily concerned with industrial development). GROW, SPREAD, and SELL are the major models involved (AIR is also involved in specific

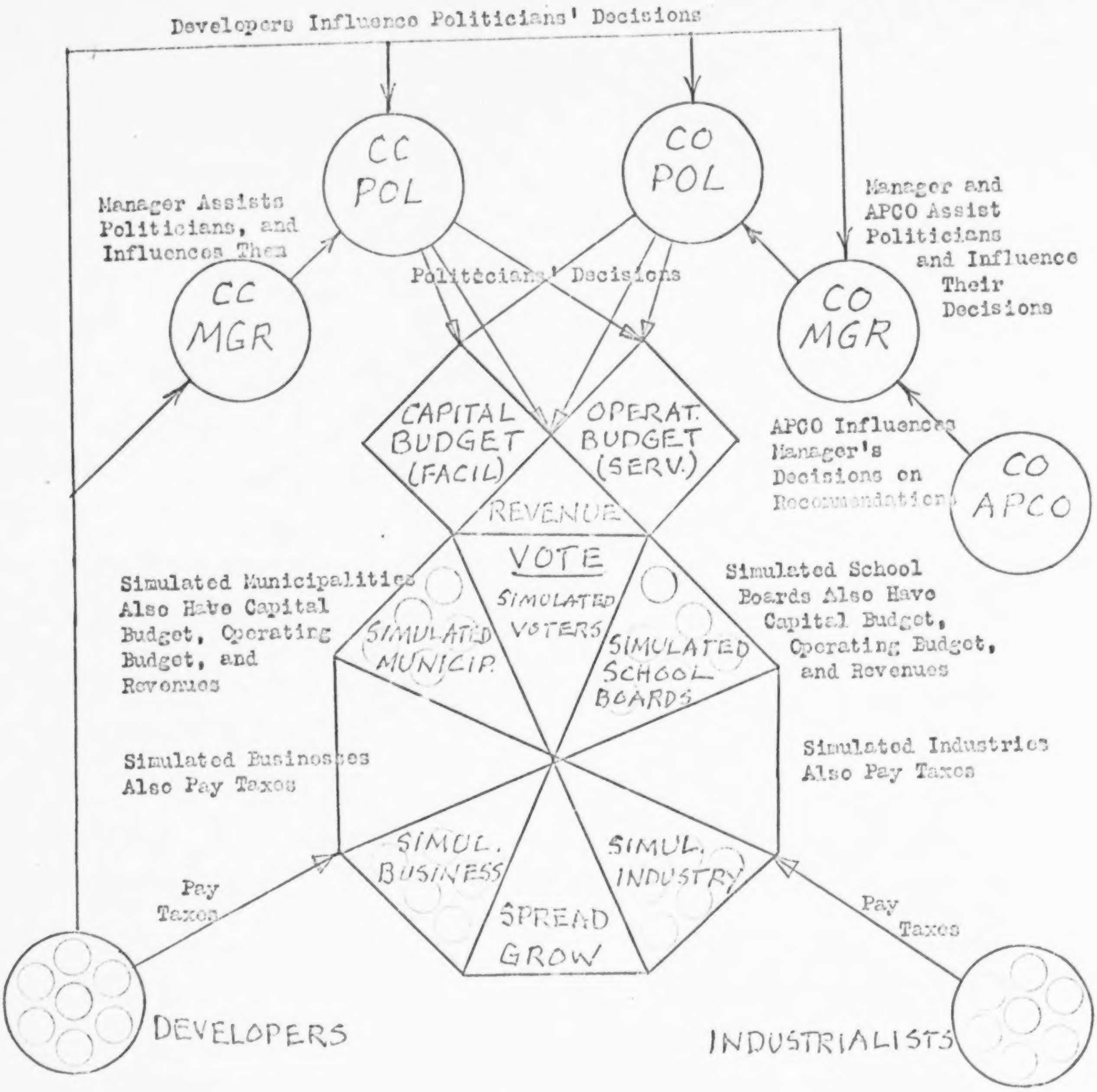

Developers Influence Politicians' Decisions
CC POL
CO POL
Manager Assists Politicians, and Influences Them
Manager and APCO Assist Politicians and Influence Their Decisions
Politicians' Decisions
CC MGR
CO MGR
CAPITAL BUDGET (FACIL)
OPERAT. BUDGET (SERV.)
REVENUE
APCO Influences Manager's Decisions on Recommendations
CO APCO
VOTE
SIMULATED VOTERS
Simulated Municipalities Also Have Capital Budget, Operating Budget, and Revenues
SIMULATED MUNICIP.
Simulated School Boards Also Have Capital Budget, Operating Budget, and Revenues
SIMULATED SCHOOL BOARDS
Simulated Businesses Also Pay Taxes
Simulated Industries Also Pay Taxes
SIMUL. BUSINESS
SIMUL. INDUSTRY
SPREAD GROW
Pay Taxes
Pay Taxes
DEVELOPERS
INDUSTRIALISTS

Figure 19

LOCAL PUBLIC FINANCES INTERACTIONS

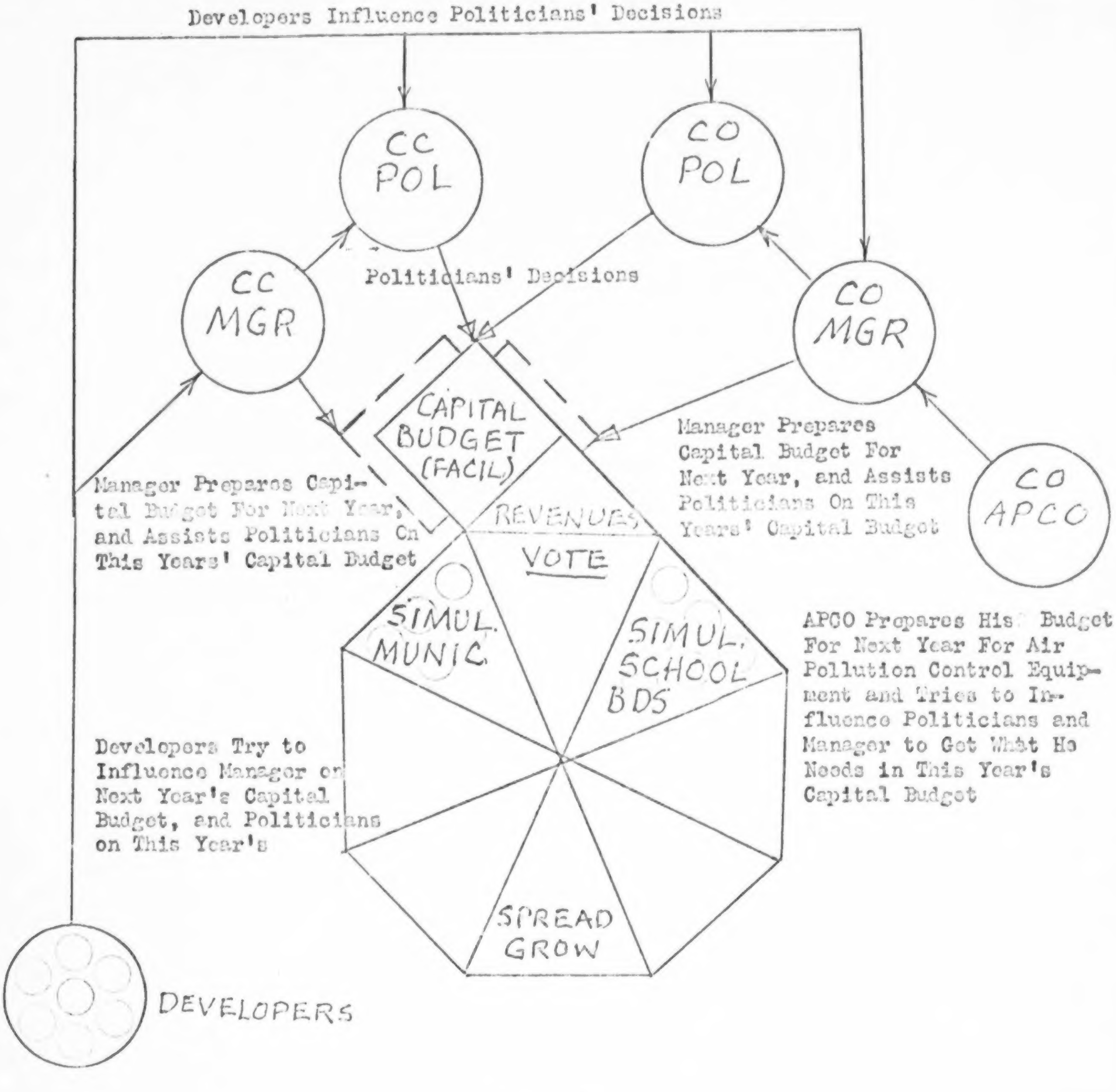

Developers Influence Politicians' Decisions
CC POL
CO POL
CC MGR
CO MGR
Politicians' Decisions
CAPITAL BUDGET (FACIL)
REVENUES
VOTE
SIMUL. MUNIC.
SIMUL. SCHOOL BDS
SPREAD GROW
Manager Prepares Capital Budget For Next Year, and Assists Politicians On This Years' Capital Budget
Manager Prepares Capital Budget For Next Year, and Assists Politicians On This Years' Capital Budget
CO APCO
APCO Prepares His Budget For Next Year For Air Pollution Control Equipment and Tries to Influence Politicians and Manager to Get What He Needs in This Year's Capital Budget
Developers Try to Influence Manager on Next Year's Capital Budget, and Politicians on This Year's
DEVELOPERS

Figure 20

LOCAL PUBLIC FACILITIES INTERACTIONS

ways which will be covered under air pollution control). The most significant interactions are illustrated in Figure 21, which shows how the simulated real estate market enters in, as well as the simulated developers and industrialists. Residential development obviously also involves the several types of simulated households, demanding and buying homes in various analysis areas.

Exofirm Location

Decisions about the entrance and location of new industrial firms within the metropolitan area involve chiefly the gamed roles. Politicians, Managers, Developers, and Industrialists may interact, as they try to influence the exofirm to locate in the particular area they are interested in so that increased public or private revenues will add to their disposable funds. The APCO may also be involved in considering the air contamination impact of the particular type of industry, or its specific location. All roles and models will be affected by the new employment, through GROW and SPREAD. The set of major interactions on exofirm decisions is shown in Figure 22.

Air Pollution Control

County Politicians, Manager, and APCO, along with the Industrialists, will be the major roles concerned with air pollution control decisions. Central City roles (and possibly the simulated municipalities) will also be concerned as possible contaminant generators through operations of incinerators, major heating loads, and so on. Here, of course, the major model involved is AIR, but GROW and SPREAD will also affect the general levels of pollution of simulated industries, businesses, and households (including their automobile and truck traffic). The most important subroutine is the calculation of financial statements

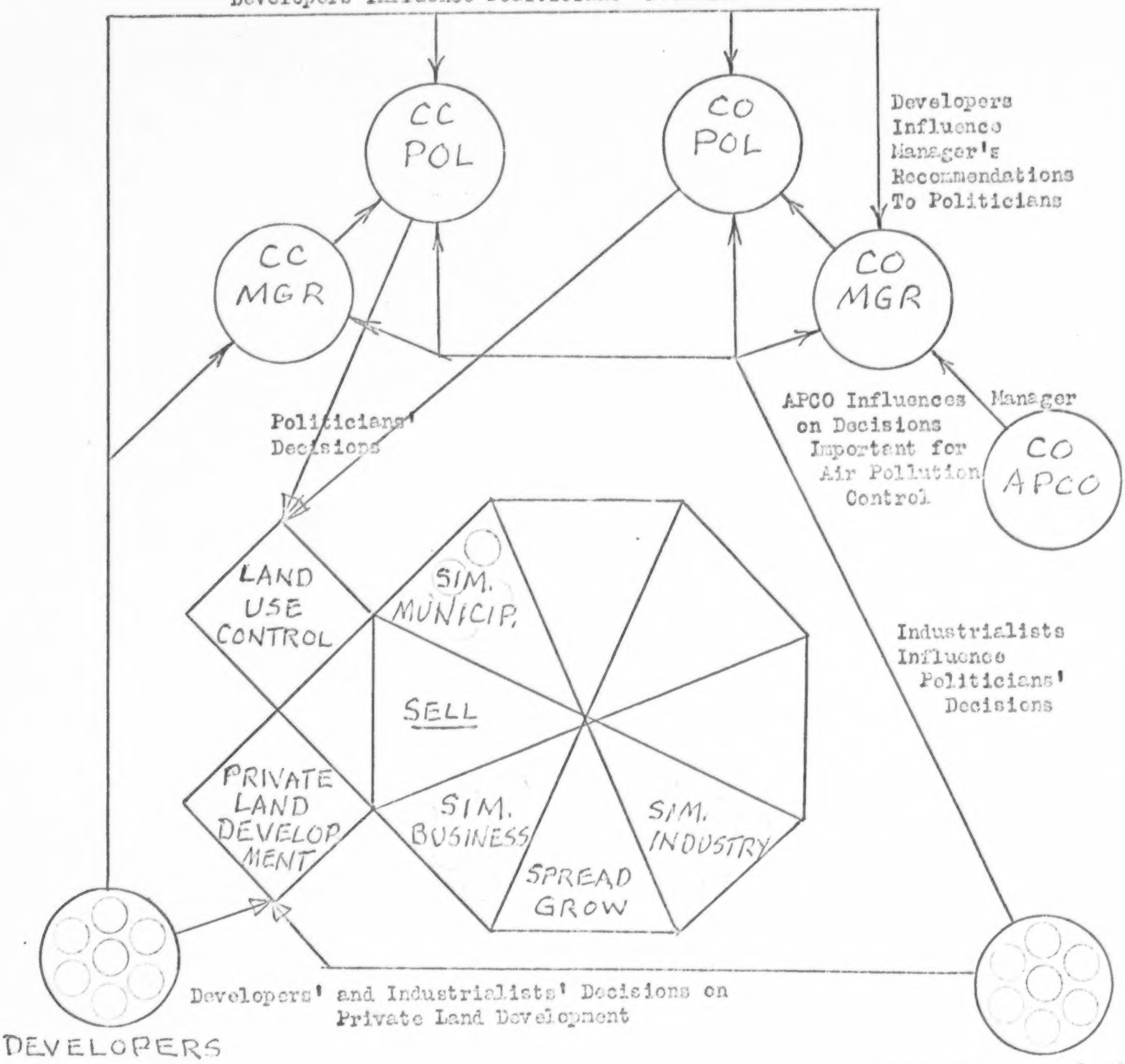

Developers Influence Politicians' Decisions
CC POL
CO POL
Developers Influence Manager's Recommendations To Politicians
CC MGR
CO MGR
Politicians' Decisions
APCO Influences on Decisions Important for Air Pollution Control
Manager
CO APCO
LAND USE CONTROL
SIM. MUNICIP.
SELL
PRIVATE LAND DEVELOPMENT
SIM. BUSINESS
SPREAD GROW
SIM. INDUSTRY
Industrialists Influence Politicians' Decisions
Developers' and Industrialists' Decisions on Private Land Development
DEVELOPERS
INDUSTRIALISTS

Figure 21

PRIVATE LAND DEVELOPMENT INTERACTIONS

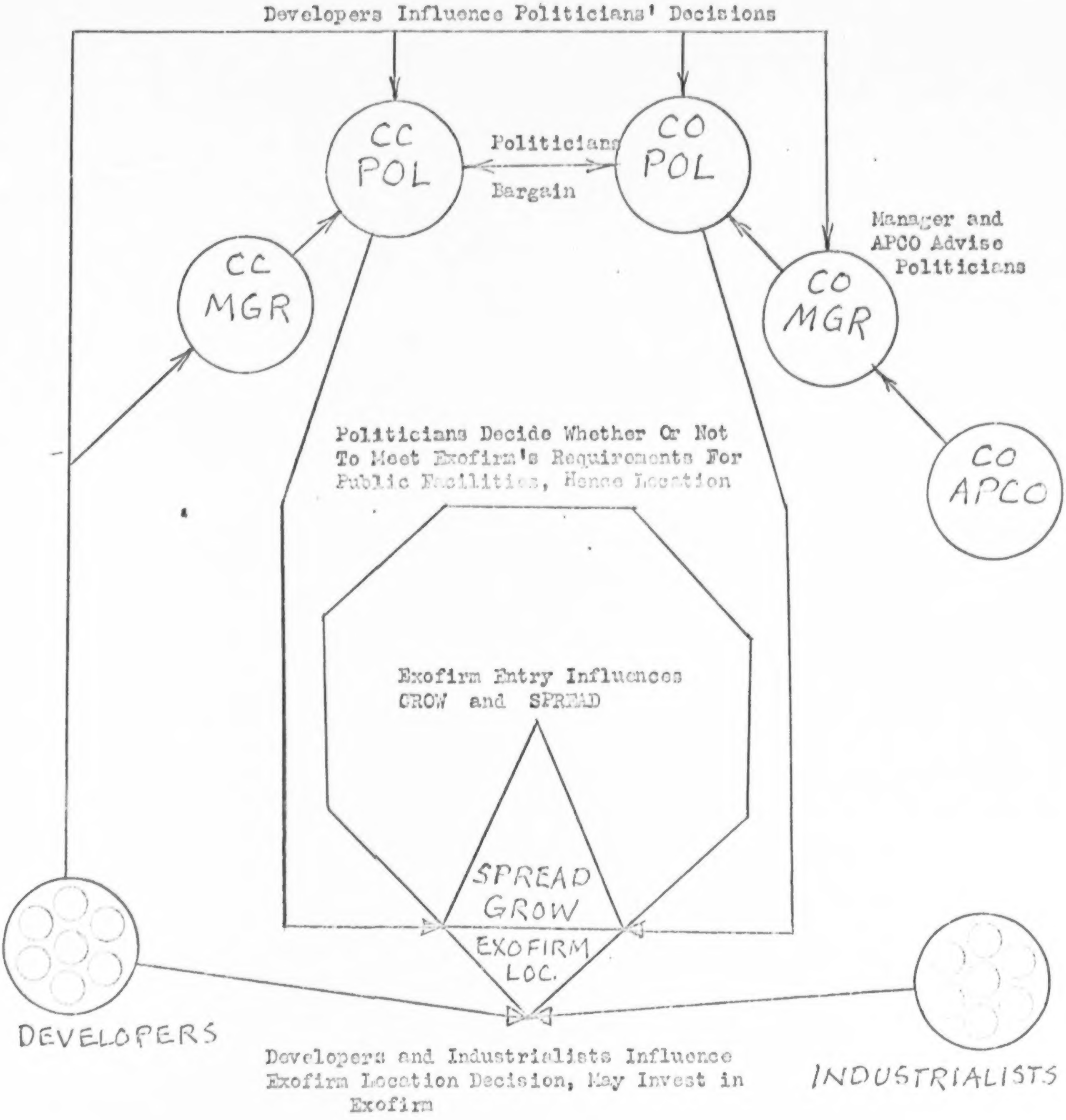
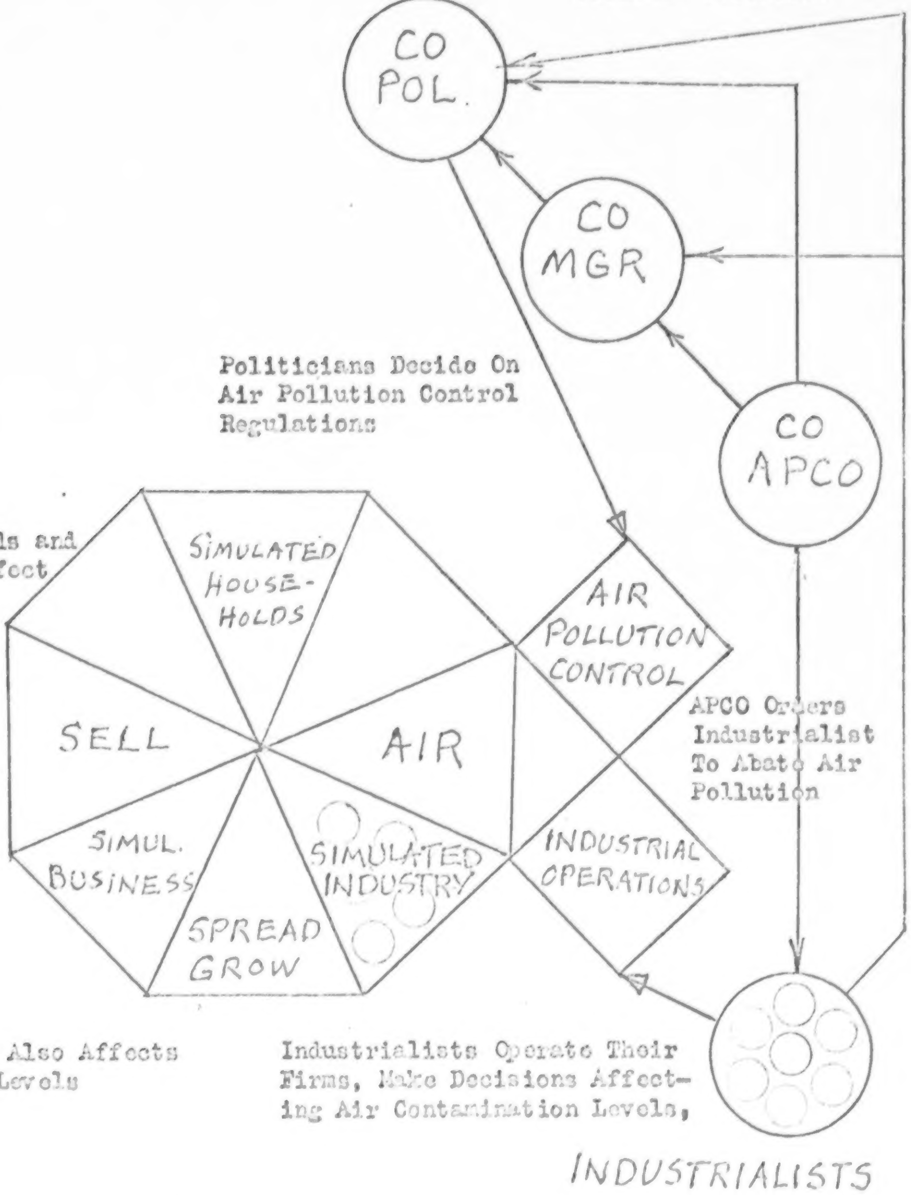

Developers Influence Politicians' Decisions
CC POL
Politicians Bargain
CO POL
CC MGR
Manager and APCO Advise Politicians
CO MGR
CO APCO
Politicians Decide Whether Or Not To Meet Exofirm's Requirements For Public Facilities, Hence Location
Exofirm Entry Influences GROW and SPREAD
SPREAD
GROW
EXOFIRM LOC.
DEVELOPERS
Developers and Industrialists Influence Exofirm Location Decision, May Invest in Exofirm
INDUSTRIALISTS

Figure 22

EXOFIRM LOCATION INTERACTIONS

(which indicates the funds available for inspections in the current year and probably the monitoring station installations that have been approved). The newspaper generator also responds to air contamination levels. These interactions are shown in Figure 23.


CO POL.
CO MGR
CO APCO
AIR POLLUTION CONTROL
INDUSTRIAL OPERATIONS
SIMULATED HOUSE-HOLDS
SELL
AIR
SIMUL. BUSINESS
SPREAD GROW
SIMULATED INDUSTRY
INDUSTRIALISTS

Industrialists Try To Influence Politicians' Decisions

Politicians Decide On Air Pollution Control Regulations

Simulated Households and Businesses Also Affect Air Contamination Levels

Air Contamination Levels Influence Values of Land and Buildings

APCO Orders Industrialist To Abate Air Pollution

Simulated Industry Also Affects Air Contamination Levels

Industrialists Operate Their Firms, Make Decisions Affecting Air Contamination Levels,

Figure 23

AIR POLLUTION CONTROL INTERACTIONS

GAMING OPERATIONS

Unlike computer operations, gaming operations can never be completely programmed. If they could be, it would be possible to model them with computer programs. And even if they could be, the learning opportunities of gaming would be lost. For the gaming activities are the unique and different aspect of gaming-simulations, with unpredictable, real live people involved in activities within some major constraints, or "rules of the game", which the operators hope those people will follow. And the gaming operators are also human beings, which means that their behavior during gaming operations is also unpredictable.

No matter how carefully the gaming-simulation builders have done their work, the actual people who fill the decision roles in any given instance will bring to gaming activities their own ideas about the metropolitan environment and the kinds of decision roles and decisions involved. They will inevitably bring along their own stores of experiences, what they have heard and read or directly experienced. And they will bring along their own capacities for understanding and working with various kinds of information, which must be taken into account as fully as possible in preparing materials.

Since one of the major aims of gaming simulation is to help players to alter their views where those are incorrect or limited, or to reinforce them where they are correct, it is vital that the complete set of gaming operations be viewed from the standpoint of those players in working out the rehearsals, staging setting, properties, direction and prompting that will be required during the gaming sessions. As this suggests, the gaming simulation builders and gaming operators might be viewed as preparing and putting on a drama, but one in which there is no set script but only a set of general constraints within which the players must improvise.

The game operators will have considerable effect on any gaming session, depending partly on how they permit their own ideas about the simulated environment and gamed roles to color the ways in which they introduce players to their roles, the general guidelines they give at the beginning and during gaming, and the specific advice or information which they pass on when faced with specific questions from players. Gaming operators who are different people from those who built the gaming simulation will inevitably reflect different views in this way than will those who worked it out in detail.

Gaming participants will find that their motivation and their effectiveness in gaming sessions is greatly influenced by the whole setting in which they find themselves. The introductory materials and presentations by the gaming operator, the available reference materials, the format of the computer output and decision forms, the gaming room and its equipment will all affect their behavior as they face the complex decisions and interactions expected of them. It is expected that their own personalities will enter in, since that is one of the reasons for gaming these decisions and interactions. But the personalities of the game operators may also influence the behavior of participants. And the evident organization or disorganization of the operator or operating team will also have its effects. All of these will lead to many uncertainties for any given gaming session.

PRE-GAMING PREPARATIONS

Careful preparation is needed if players are to enter into the early gaming period with a minimum of confusion. At this point the player is trying to understand what is expected of him, what gaming simulation is all about, what decisions he must make, what information he can get, what other players are doing, and the possibilities of interaction. It is especially important to provide him with introduction and preparation which will help him to get past the inevitable initial frustrations and uncertainties, but without at the same time rigidly structuring his later gaming behavior.

Some general introduction to the purposes and potentials of gaming simulation is required, yet it is also critical to begin actual gaming--since that is really the best way to begin to understand it. For this purpose it has proved useful to start with some simpler gaming simulations, such as the Community Land Use Game, Metropolis, or Comexopolis. In some cases, it may be worthwhile to include some cycles of METRO/AP, which includes some features not found in APEX, but which has the same basic simulated metropolitan environment. Then it is probable that less introduction to APEX will be necessary, though there is also the possibility of later confusions between the two.

Before the initiation of APEX, each player should be provided with a set of pre-game study materials. This should contain an overall description of APEX, including its purpose in the APCI program; a brief history and description of the simulated metropolitan area, a discussion of the underlying assumptions and models of APEX, and brief descriptions of all the gamed roles (perhaps at about the level contained in the earlier parts of this report). This material should include the general interaction diagram (Figure 17), and a copy of the glossary of terms and reference tables, to acquaint him with the special terminology used in APEX and some of the basic tools he will be using in making his decisions. If possible, this pre-game packet should all be bound together and distributed early enough so that it can be assumed that players have studied them before the first APEX gaming period.

At the beginning of the first gaming period, the gaming operator will make an initial verbal presentation, accompanied by films, slides, tapes, and other audio-visual materials. This session will be aimed primarily at answering players' questions about the pre-game materials they have studied, and further expanding on the contents of those materials. At this time the operator has the difficult task of motivating players sufficiently to carry them through the inevitably trying period when they are first faced with the unavoidable mass of computer output, player manuals, decision forms, and all the other paraphrenalia of the actual gaming operations. For this purpose he can draw on films or slides giving visual images of the simulated city and metropolitan area, on such special films as the SYMAP film showing the historical spatial development of Lansing, a brief sound film or video tape of some previous run of APEX, and any other device he can develop to give participants some feel for the general characteristics of the community they are going to deal with and some idea about the general behavior that is expected of them.

Just before he begins the first cycle of APEX, each player will be given a set of role manuals for his particular gamed role. One manual will be a large binder containing sample computer output from some present cycle for that particular role, containing the data on which he will base his first set of decisions. This output will be annotated to draw his attention to relevant information and to the proper forms to be used to input the decisions which result from each item of output. It will also include notes explaining the meaning of each output item and some of the reasons behind the decisions recorded in that output. (The contents of the computer output to each player are describer below under "Gaming-Computer Links.") The output from each succeeding cycle of gaming will be added to this binder, building up a history of the decisions of each player over the entire run.

The second manual will contain a more detailed description of the role of the particular player, a copy of the glossary of terms, reference tables, copies of each of the decision forms, brief instructions for using those forms, and references to the pages of computer output where the decisions are eventually recorded. Each player is expected to read his detailed role description and computer output carefully before he begins to make decisions or interact with other players about them. The rest of this manual is intended as reference during the actual gaming period.

Before gaming actually begins, the operator should call the attention of all players to the various kinds of information which are available to him in the gaming room, as wall displays or as reference materials. These materials will become more significant to him as he begins to make specific decisions, since they will help him to understand some of the background about the simulated environment in greater detail.

The wall displays in the gaming room will include the following major items, but additional displays will undoubtedly be developed by the operators of APEX as they gain more experience with its operation:

1. A land use map of the simulated metropolitan area.
2. A computer-generated newspaper for the current cycle.
3. A chart showing the changes in households and employment, for the current cycle.
4. New demand for residential, commercial and industrial property, per analysis area, for the current cycle.
5. A general summary of population, employment, revenues, and expenditures for each jurisdiction (gamed and simulated, including schools) for the current cycle.
6. A table of market-owned property distribution by use and, if vacant, by zoning category, per analysis area, for the current cycle.
7. A table showing the current average market values of property by developed use or, if vacant, by zoning category, per analysis area.

8. A table giving the current cycle's sales price for each developed land use type in each analysis area.
9. Local public expenditures in each analysis area, accumulated through the current cycle, for each of the six types of public capital plant, together with the capital plant indices and ranking of all analysis areas.

As each cycle's set of the above tables is available as computer output, each should be posted on top of the preceding cycle's tables. Keeping them together in order permits players to check what changes have occurred over time. However, the newspaper should only be posted for the current cycle, to avoid confusion; with Newspapers from preceding cycles being placed in a binder for reference.

Analysis area reference manuals will also be available in the gaming room. These will each contain photographs of typical residential, commercial, and industrial land use and buildings for that area, as well as photos of some existing public capital improvements. They will include both verbal and tabular descriptions of population and land use characteristics, an inventory of all existing public facilities with data on size, costs, and so on. Those reference manuals are available for use at any time during the gaming period (and perhaps at other times as well) for use by players wishing to obtain more information about particular parts of the metropolitan area.

Generally, one cycle of the game will be played in a half day. Players should first be given an opportunity to study their computer output, read the new newspaper, and consult the wall charts to see the effects of the previous cycle's decisions. After perhaps a half hour, there should be a brief general discussion, led by the gaming operator, in which the events of the previous cycle are clarified and explained. This is followed by discussions, among jurisdctional teams, of the issues which have been presented to each team in the newspaper. After a decision on these issues, each player enters into his own decision-making period, in which he performs the duties required of his role, consulting with other players as he desires and as the occasion arises. After all the decision forms have been handed in to the gaming operator, (and checked for errors), players are finished with that cycle and the decisions are prepared for input to the computer.

GAMING PERIOD PREPARATIONS

In addition to preparing the participants and launching them into the early APEX cycles, game operators will also be concerned about their own preparations for the actual gaming period. They will need to think through as thoroughly as possible the setting of the gaming room and its equipment, the organization and training of the gaming operator team, and the kinds of information which will be made available to the players. Each of these are critical parts of the overall staging of APEX, establishing the milieu for satisfaction or frustration of the players. Operators should also be concerned for the possible desirability of providing refreshments or meals for players, especially if the gaming period is expected to extend into or over some regular meal time.

The gaming room itself will include adequate tables for the various players or teams to operate, including sufficient space for spreading out the many materials players will be using. Operators may wish to experiment with various arrangements, including separation of teams for Central City from those for County, with Developers and Industrialists having their own separate group tables or seating all players around one central table. These arrangements will have important impacts on the actual interactions which take place. Where teams are separated it may be possible to provide telephone or intercom links for interactions. The gaming room should also provide plenty of room for posting the wall displays already discussed, as well as any other materials which the operators or players may wish to make available. Suitable shelf space should be provided for reference manuals and other materials that are not posted as wall displays. Adequate lighting is an obvious necessity.

Ideally, the gaming room will be immediately adjacent to the computer room. Such proximity is especially necessary for APEX, where the AIR model is expected to be operated during the gaming period, with output to players and with player decisions being input to the computer. Although there is no need for players to be in the computer room, this also provides them with an opportunity to observe regular computer operations. More sophisticated arrangements, such as cathode ray tube displays and other output devices may also prove useful in further refinements of the APEX operations.

Slide and film projectors, along with audio and video tape equipment, may be needed for the pre-gaming preparations, but they may also be useful during the gaming period. Additional films and slides may be shown at the beginning of later cycles, dealing specifically with areas or projects about which decisions must be made. Video tapes might be made of early gaming sessions, then replayed during critique sessions. Gaming operators will undoubtedly think of other useful equipment, such as overhead projectors, which can be usefully employed.

No matter how carefully the players are prepared for beginning cycles, they will need a good deal of help as they start to make decisions. Trained operators should be available to assist them, with at least one operator sitting with each jurisdictional team during the first several cycles. He should be prepared to answer many very specific questions about the availability of information, the meaning of specific items, and the reasons for a variety of things. Operators may also have to prod players to make required decisions and to check their decision forms before those are turned in, especially during the first few cycles when players will unavoidably want to take more time than can be allowed.

This means that the operator team must be trained and organized to perform all the gaming period tasks, including advising players, posting information, taking in decision forms, punching the appropriate cards for computer operations, and so on. Policies should be established (but not too rigidly) about the levels of advice to give players during gaming, including what to tell them and what not to tell them (not because anything should be kept secret but because too much detailed information may be confusing rather than helpful). Operators who know APEX in detail will generally be inclined to answer simple player questions much too fully, even bringing up other matters not relevant to these questions. The general impression which the operator team gives to the players, whether well organized, informed, and helpful but not overly directive or disorganized, poorly informed, and unhelpful or too positive, will make considerable differences as the players try to increase their understanding and competence with each cycle of gaming.

The form in which information is made available to players is critical. Computer output and decision forms can be overwhelming, especially if not well designed with the players perspective in mind. Computer output can be improved considerably by various forms of graphic printout, such as data mapped by analysis area, as well as in complex tabular form. Decision forms, and decision guides of various kinds, should also be carefully thought through and prepared so as to help players but not structure their behavior too rigidly. APEX builders and APCI operators will need to spend considerable time on the detailed development of all forms of information which will be provided to the players, seeking to make it both useful and readily available, and trying to present information in many ways so that different players can comprehend and apply it.

Encouraging player interactions is sometimes the most difficult part of gaming operations. So many interactions are possible, and so many are really desirable, that constraints of time and setting never permit them all. Much can be done in pre-game briefing, in preparation of room and equipment, and in operator advice to players. Operator attitude will always made considerable difference, since players will continually be looking to the operators for clues about what behavior is expected of them. Yet operators will not want to give the impression that certain interactions are absolutely necessary, since that might focus player attention on some interactions in their limited gaming time, leaving out other interactions which the players themselves would have chosen. APEX operators should continually experiment with various ways to create an environment in which many kinds of player interaction can take place.

GAMING-COMPUTER LINKS

Interactions between players and computer have been presented in many ways already. Discussions of the simulated metropolitan environment; the gamed decision roles; problems, decisions, and issues; and decision-centered interactions have all referred to the many links between the gaming and computer portions of APEX.

This section carries this concern about player-computer relationships one step further in detail. It will deal with some of the features of the timing of gaming and computer operations, including the cycles, runs, and rounds of APEX operations. And it will present a great deal of quite detailed information about the computer outputs to players and the computer inputs from players, in the form of detailed listings of specific items of information and their sources.

Relations between the gaming and computer portions of APEX can be looked at either from the perspective of the player or the computer. In the discussion of gaming operations, the player perspective was emphasized. There it would have been appropriate to talk about the player inputs from the computer and the player outputs to the computer. But here the discussion will be from the perspective of the computer, so that it will refer to computer outputs to the player and computer inputs from the player. This seems to be a well-established convention for all operations hinging around computer simulations, so that output always means computer output and input always means computer input. This convention will be followed here, but it is important to recognize that computer output is always input to operator or player, while computer input is always output of operator or player.

GAMING-COMPUTER TIMING

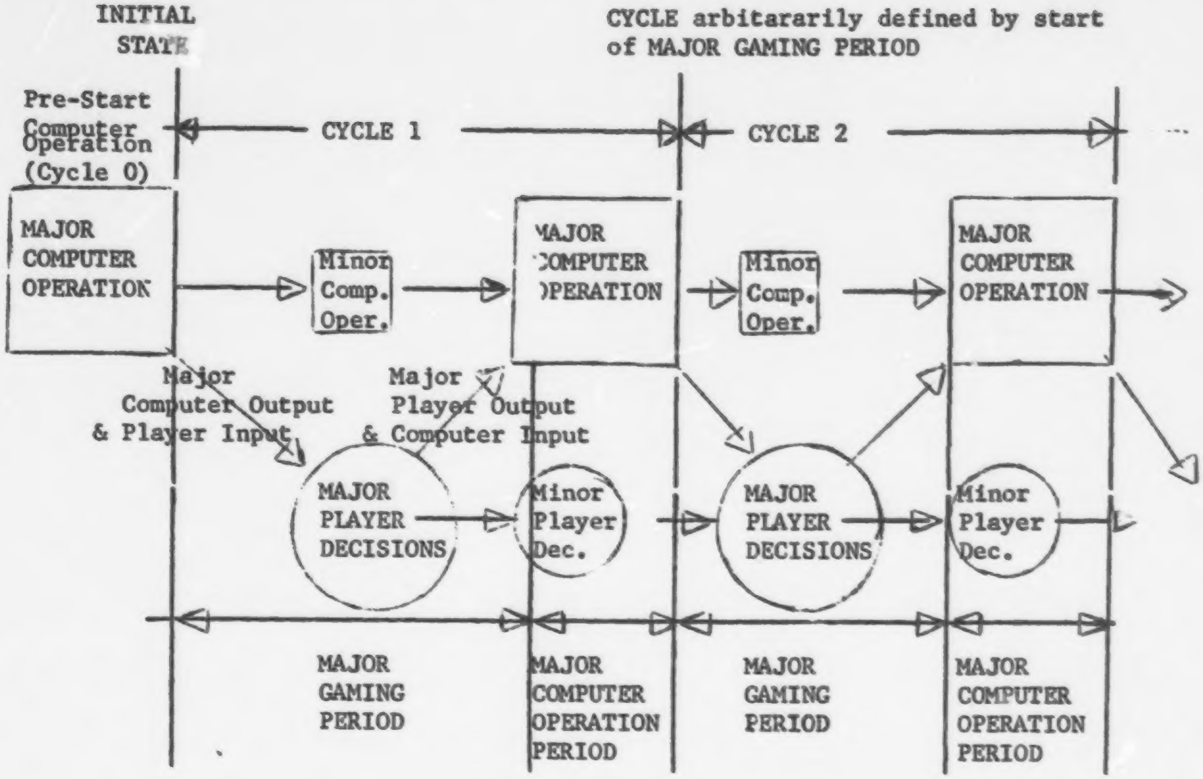
Gaming requirements tend to set the timing for gaming-simulations, while computer operations establish certain timing constraints. For this reason it is useful to start with some simple definitions for the various time periods involved, especially the cycle, round, and run and the gaming and computer operations periods. These are especially necessary for APEX where most of the operations are assumed to be on an annual cycle, while certain AIR model and air pollution control operations are assumed to involve quarterly cycles.

The major gaming period sets the benchmarks for the rest of the timing, as shown in Figure 14. The beginning of this gaming period establishes the beginning of a cycle, with the end of that cycle coming at the beginning of the next major gaming period. Major computer operations can then take place at any time between the end of the major gaming period and the beginning of the next major gaming period.

Each cycle begins with the provision of computer output and other information to the participants. They immediately move into the major gaming period, studying the available information, interacting with other participants and with the game operators, making their routine and special decisions, then turning their decision forms into the operator. This completes the major decision period. Major computer operations can then take place at any time before the next scheduled major gaming period.

In continuous runs the next gaming period tends to start as soon as the major computer operations are completed and the computer output is ready to hand to the players. In discontinuous runs the next gaming period may be scheduled for several days or a week later. Then the computer operations may be carried out at any time during the inter-

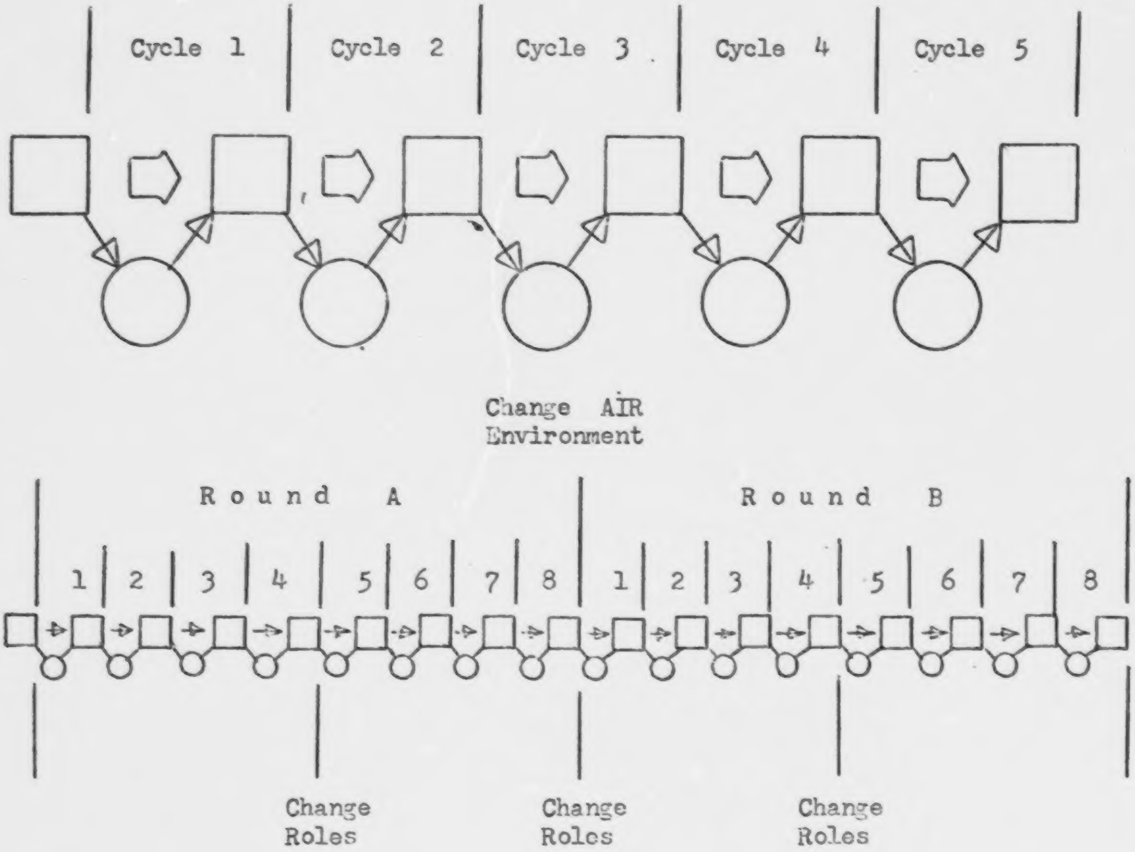
Figure 24


INITIAL STATE
CYCLE arbitararily defined by start of MAJOR GAMING PERIOD
Pre-Start Computer Operation (Cycle 0)
CYCLE 1
CYCLE 2
MAJOR COMPUTER OPERATION
Minor Comp. Oper.
MAJOR COMPUTER OPERATION
Minor Comp. Oper.
MAJOR COMPUTER OPERATION
Major Computer Output & Player Input
Major Player Output & Computer Input
MAJOR PLAYER DECISIONS
Minor Player Dec.
MAJOR PLAYER DECISIONS
Minor Player Dec.
MAJOR GAMING PERIOD
MAJOR COMPUTER OPERATION PERIOD
MAJOR GAMING PERIOD
MAJOR COMPUTER OPERATION PERIOD

DEFINITION OF COMPUTER OPERATION AND GAMING PERIODS, AND COMBINED GAMING-COMPUTER CYCLE

Figure 25

CYCLES, ROUNDS, AND RUNS IN APEX


Cycle 1
Cycle 2
Cycle 3
Cycle 4
Cycle 5
Change AIR Environment
Round A
Round B
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
Change Roles
Change Roles
Change Roles

RUN: Continuous cycles of rounds with one group, no matter how many cycles or rounds.

CONTINUOUS RUN: Cycles take no more time than that required for gaming period followed by computer processing period, followed immediately by another cycle. A continuous run is several cycles, usually in the same day.

DISCONTINUOUS RUN: Extra time between gaming periods - more than required for computer processing. Usually a discontinuous run is several cycles or rounds, with the gaming period for each cycle on a separate day.

vening time. In continuous runs player interaction tends to take place while the computer operations are carried out. In discontinuous runs some interaction may take place sporadically between gaming periods, or formal interaction may be scheduled (as for MAPCORE exercises) or time may be scheduled for informal, unprogrammed interaction.

Computer operations can be accomplished at any time before the start of the next gaming period, but it is advisable to carry them out in sufficient time to allow for possible computer problems. Earlier processing will also make it possible to post computer output before the start of the next gaming period, if that turns out to be desirable as an opportunity for players to study and interact about the results of their most recent decisions. Timing of computer operations may also be influenced by the way in which special decision exercies, like MAPCORE, must feed into APEX. If that special exercise results in information which should become part of the computer input for processing before the next gaming period, then the computer operations must wait till after the special exercise is finished. However, it seems likely that most such special exercises will mostly provide information which players will use in making the normal decision during the next regular gaming period.

Running the AIR model during the normal gaming period, so that the APCO and Industrialists can operate on a reasonable facsimile of an "on-line" basis, means that the AIR model will run separately from the major computer operations. This minor computer operation will provide quarterly output to the APCO, and it will respond in certain ways to quarterly decisions by the Industrialists and the APCO (for general emergency and alert orders). This means that the computer will be tied up for the gaming period. The AIR model will also run with the major computer operations, processing the final set of decisions by APCO and Industrialists and providing them with the results at the beginning of the next gaming period. At this time the AIR model will also feed certain accumulated effects of its operations into the other primary models of the APEX computer-simulated environment, working out the consequences to the community of the past years' history of air characteristics and air contamination. Figure 25 shows a general representation of computer and gaming operations for APEX, including the AIR model and its links to APCO, Industrialists, and major computer operations.

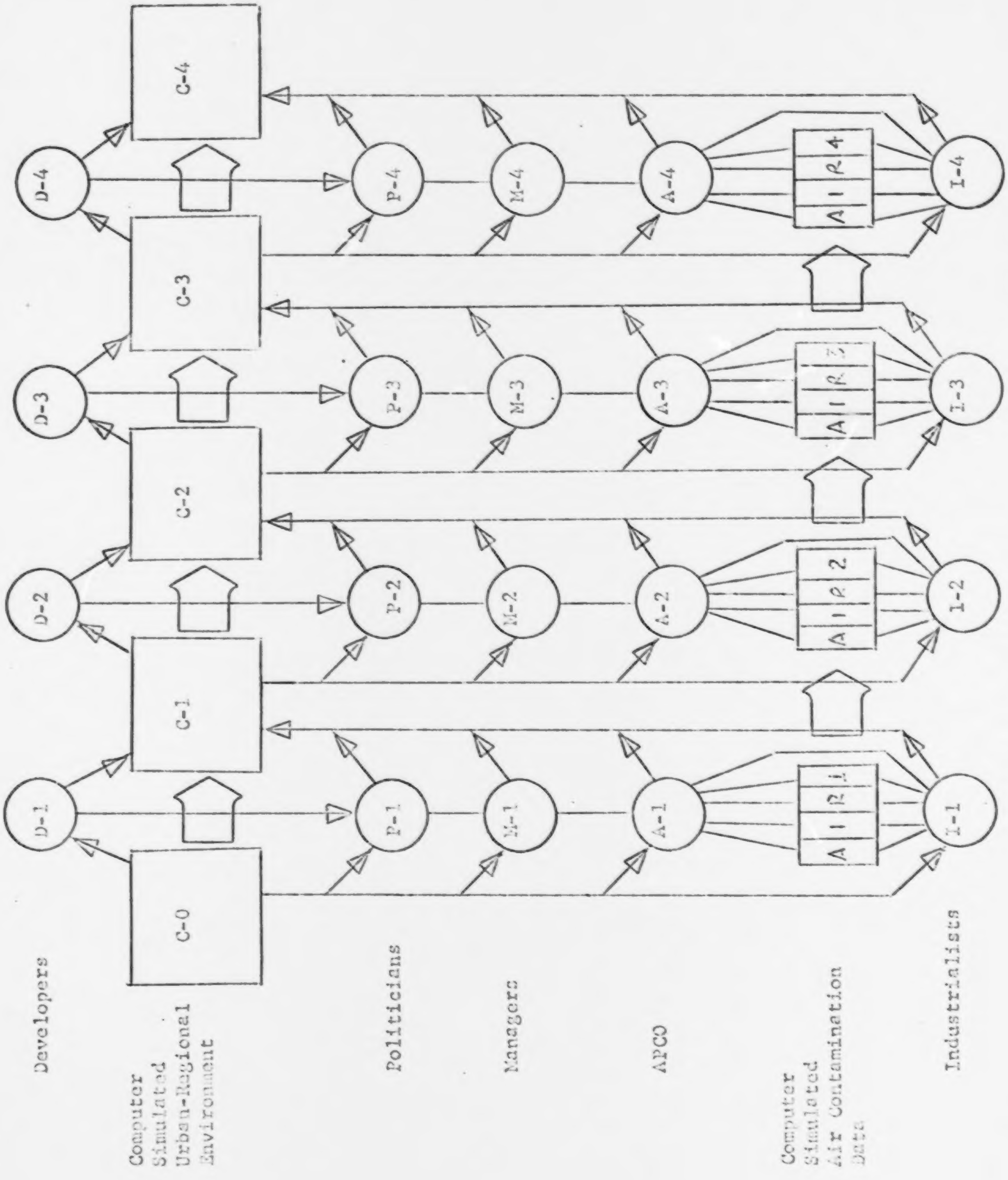
COMPUTER OUTPUT TO PLAYERS

At the beginning of each cycle of APEX, the various players will receive output from the computer, representing the results of computer simulation operations on the decisions fed into the computer after the last gaming period (or preset output for the first cycle in an APEX run). One major set of computer output will be "General Computer Output Posted In Gaming Room" as listed on the immediately following pages. This general computer output provides general information of interest to all players, including summary tables for the whole metropolitan area, (by analysis area), financial data for each jurisdiction, and the community newspaper (the APEX STAR).

In addition, each player (or team of players) will receive a separate set of output which is most relevant to his role. This output is listed on the pages immediately following the "General Computer Output," under the headings of "Computer Output to Politicians and Managers," "Computer Output to Air Pollution Control Officer," and so on. Here each player will get detailed data which is of most significance to him as he starts to make his regular decisions.

Figure 26

APEX MAN-MACHINE INTERACTIONS


Developers
Computer Simulated Urban-Regional Environment
Politicians
Managers
APCO
Computer Simulated Air Contamination Data
Industrialists
D-1
D-2
D-3
D-4
C-0
C-1
C-2
C-3
C-4
P-1
P-2
P-3
P-4
M-1
M-2
M-3
M-4
A-1
A-2
A-3
A-4
AIR 1
AIR 2
AIR 3
AIR 4
I-1
I-2
I-3
I-4

Most of this computer output to players is printed out for the regular, annual cycle. But the APCO will receive data on air characteristics on a quarterly basis, as listed under his computer output, representing the information he will get from installed monitoring stations and specific spot inspections he has requested (and paid for). The APCO will receive this special air data at the beginning of each regular cycle and then three more times during the normal gaming period.

GENERAL COMPUTER OUTPUT POSTED IN GAMING ROOM

Each cycle of APEX a set of general computer output is posted on the walls of the gaming room. In addition, copies of these items are given to the Managers to guide their decision-making. General tables are printed out by the computer in the following order:

CHANGE IN HOUSEHOLDS AND EMPLOYMENT

A.A.	Household types*					Local Commerce	Regional Commerce	Bureaucratic	Endogenous Industry	Exogenous Industry
	1	2	3	4	5					
1										
:										
:										
29										

Figures appearing in each of these cells may be either positive or negative

DEMAND FOR NEW HOUSING AND NON-RESIDENTIAL PROPERTY

A.A.	Land Use Type*						
	R-1	R-2	R-3	R-4	Loc. Com.	Reg. Com.	Industrial
1							
:							
:							
29							

Figures appearing in any cell may be either positive or negative.

GENERAL SUMMARY INFORMATION

		Simulated Municipalities				
	Central City	S A	B	C	D	E
Revenue						
Tax Rate (City, Cty., Schools)						
Total Assessed value						
Total taxes						
Non-tax revenue						
Expenditures: Total and %						
City						
Schools						
Population Total-%						
By Household Types 1-5						

GENERAL COMPUTER OUTPUT POSTED IN GAMING ROOM

Capital Plant Distribution
  by Types (Total-%)
  - Streets
  - Sewers
  - Water
  - Parks
  - Misc.
  - Elem. Schools
  - High Schools
    - Total CP Index

Employment (Totals-%)
- Local Commerce
- Reg. Commerce
- Bureaucratic
- End. Industry
- Exo. Industry

Credit Standing Cities
Credit Standing County

Accreditation rating of High Schools

MARKET-OWNED PROPERTY DISTRIBUTION'

A.A.	Land Use Type								Vacant Zoning Category*				
	R-1	R-2	R-3	R-4	L.S.	R.S.	IND.	Ag.	R	M	C	I	A
1													
:													
:													
:													
29													

Figures in any cell will be positive. For developed residential land, all figures refer to dwelling units; for non-residential developed property and vacant land, figures are in acres.

AVERAGE ASSESSED VALUE FOR VACANT AND IMPROVED PROPERTY

A.A.	Land Use Type	Vacant Zoning Category
1	As above.	
:		
29		

---

* See Glossary for definitions

' Property Distribution tables for Developers and Politicians follow this same format.

GENERAL COMPUTER OUTPUT POSTED IN GAMING ROOM

CAPITAL PLANT INDICES BY CATEGORY

A.A.	Streets			Water			Sewers			Parks			Misc.			ELEM. SCH.			H.S.		
	Amt.	Index	Rank	A.	I.	R.	A.	I.	R.	A.	I.	R.	A.	I.	R.	A.	I.	R.	A.	I.	R.
1																					
:																					
:																					
29																					

NEWSPAPER (APEX STAR)

National News Headlines

State News Headlines

County Issues
  Capital Plant and Health Flagged Issues

Central City Issues
  Capital Plant Flagged Issues

Business Page
  Exofirms wishing to enter the County
  Exofirms which entered the County last cycle

COMPUTER OUTPUT TO POLITICIANS AND MANAGERS

Item	Source
Results of Referenda on Bond Issues and Special Millages	Vote action and requests input by Politician
Land sales and/or purchases	Action of SELL on input decisions
Property distribution for all land in the jurisdiction, by analysis area, according to land use or vacant zoning category (see format, p.)	All players' land activities
Current cycle budget, revenues and operating expenditures, including schools (simulated)	Politician's decisions on taxes and expenditures; school simulation
Capital budget, including new and previously-voted bonds. For the Central City and County government, actual projects are listed. (For the capital improvements provided by the county to the Simulated Cities, see below.)	Politician's decisions Bonded indebtedness is accumulated from cycle to cycle.
Projects recommended by Manager but not budgeted by Politician	Comparison of Politician's decisions this cycle with Manager's decisions last cycle
Politician's standing with his constituents and with special interest groups	Calculated by ELECT on basis of Politician's decisions.
Community Standing Per capita assessed value	Assessed value (current cycle)/population
Capital Plant Index (by analysis area)	Capital Plant expenditures in all categories/population equivalent
Population (by analysis area)	SPREAD, modified by SELL
Non-white as % of population (by analysis area)	Incremented from initial value
Deterioration Index (by analysis area)	
Community Credit Rating State limit imposed on normal millage	Preset
Local limit on normal millage	May be raised to equal State limit by Politician; this must be processed by VOTE

COMPUTER OUTPUT TO COUNTY POLITICIAN's ONLY

Special millages in effect (including new)	VOTE action on Politician's request
New assessed value	Growth occurring during cycle
Revenues for next cycle	New assessed value, tax rate
Recommended Capital Improvement Program (for next year)	Manager's decisions

Each County Politician representing a simulated city will get output representing the activities of the simulated Politicians and School Board for that city. This will contain:

The Property Distribution table described above	
Financial Statement for Simulated general government and simulated schools, including both taxes and expenditures.	County Politician's decisions
Capital budget for the jurisdiction, in total dollars per budget category per analysis area	
Capital Plant table, including index and ranking, per budget category per analysis area	
Social indicators for the jurisdiction, including population, unemployment, % non-white, deterioration index.	
New assessed value for the jurisdiction	
Health Director's Decisions	Health Director's total budget request for next year

COMPUTER OUTPUT TO MANAGERS ONLY

The Manager for each of the gamed jurisdictions will receive a copy of the output for the Politician for his jurisdiction and copies of all the general tables which are posted on the wall (see below). As County Health Director, the County Manager will receive a copy of his recommendations for next cycle's Health budget, itemized.

COMPUTER OUTPUT TO AIR POLLUTION CONTROL OFFICER

Annual

Annuallythe APCO will receive a copy of the budget he has submitted to the Health Director for inclusion in the County budget. Contents are:

Monitoring	Total input by APCO
Personnel	
Equipment	New stations requested input by APCO
Supplies	
Investigations	Total input by APCO
Personel	
Equipment	
Supplies	
Public Information and Education	Total input by APCO
Legal actions	Input by APCO
Miscellaneous	Input by APCO
Total funds requested	Input by APCO
A List of monitoring stations in operation	Accumulated from cycle-to cycle from specific requests
A List of investigations made	From quarterly-cycle outputs
Regulations imposed on industry	From quarterly-cycle outputs

QUARTERLY

Quarterly, the Air Pollution Control Officer will receive reports from each of the air quality monitoring stations which he has in operation. The number of these reports will grow as the game progresses and as additional stations are put into operation. The reports record levels for any or all of seven types of pollutant: dust, particulate matter, NO_x, SO_2, CO, Hydrocarbons and ozone. Which pollutants are reported depends upon the capability of the particular monitoring stations. Information for all reports is drawn from the workings of theAir Quality Model, modified by decisions of the APCO and Industrialist. The format for the four tables follows:

COMPUTER OUTPUT TO AIR POLLUTION CONTROL OFFICER

TABLE 1

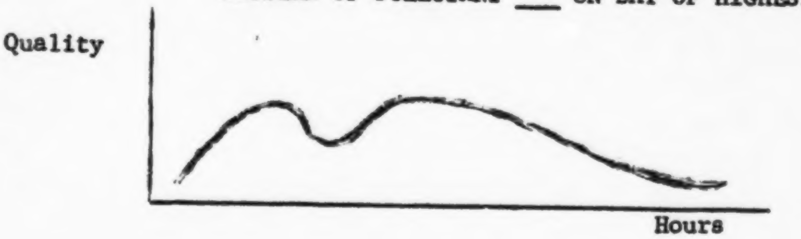
LEVEL ACHIEVED ON HIGHEST DAY OF QUARTER

A.A.	Dust	Part. Matter	NO_x	SO_2	CO	Hydrocarbons	Ozone
1							
:							
:							
N							

This table covers the entire area.

TABLE 2

PATTERN OF POLLUTANT ___ ON DAY OF HIGHEST LEVEL



This table applies to the figures in TABLE 1.

TABLE 3

HIGHEST WEEKLY LEVEL OF POLLUTION
MONITOR STATION NO. _______

Pollutant	1	2	3	4	5	6	7	8	9	10	11	12	13
Dust													
P.M.													
NO_x													
SO_2													
CO													
Hydro													
Ozone													

One of these is output for each monitoring station.

COMPUTER OUTPUT TO AIR POLLUTION CONTROL OFFICER

TABLE 4

AVERAGE OF DAILY HIGHS BY WEEK
Monitoring Station No._____

Pollutant	1	2	3	4	5	6	7	8	9	10	11	12	13
Dust													
Part. Mat.													
NO_x													
SO_2													
CO													
Hydrocs.													
Ozone													

One of these is output for each station.

The final piece of output which the APCO might get in the quarterly cycle relates to investigations he orders into the background of industries which he believes may be contributing substantially to pollution. Initially, the APCO has information which he may receive in an investigation relates to:

1) Size
   a. Employment (by household type)
   b. Acres
   c. Assessed value
   d. Age
   e. Net worth
   f. Production level

2) Pollution Characteristics
   a. Fuel
      Type
      Quantity
      Efficiency
   b. Other Contaminants

3) Market location

4) Management Location
   a. External to area
   b. Internal

5) Air Pollution Control Equipment in operation

6) Profits

How much of this information the APCO receives depends upon how expensive an investigation he undertakes.

COMPUTER OUTPUT TO INDUSTRIALISTS

Item	Source
Offer or stocks and bonds for sale and subsequent sales, including price per share.	Offers are input by Industrialist Sales and price are calculated by computer Stock Market
Dividends declared.	Input by Industrialist
Sales and/or purchases of land.	Offers to buy or sell are input by Industrialist
Rezoning requests and results	Input by Politician
Financial Statement Revenues: sales and interest on assets	Calculated by computer
Production costs Plant and equipment expenses Personnel, Including increase or decrease	Calculated by computer on basis of plant and equipment total investment (input by Industrialist) which also implies employment.
Depreciation	Calculated by computer
Promotional expenses	Input by Industrialist
Property taxes	Input by Industrialist
Campaign contributions	Input by Industrialists
GROSS PROFIT	Difference between revenues and costs.
Corporate income taxes	Computed and subtracted
NET PROFIT	Calculated after income taxes
Financial Standing Credit: Depreciated value of plant and equipment	Based on initial value updated by Industrialist's investments and calculated depreciation.
Land Value	Initial value, updated by Industrialist's investments
Value of loans outstanding	Based on loans granted by Industrialist to others.
Retained earnings and inventory	Based on Net Profit plus any unsold product

COMPUTER OUTPUT TO INDUSTRIALISTS

Debit: Stocks and bonds sold, number and value of shares	Based on initial value updated by subsequent sales by Industrialist.
Value of loans received	Initial value updated by additional Industrialist borrowing.

COMPUTER OUTPUT TO DEVELOPERS

Item	Source
Investment in an exofirm and returns, if any, on the investment.	Investments are input by Developer; returns are calculated by computer if firm enters the area.
Cash transfers to or from other players	Input by donor player
Sales and/or purchases of property, except sale of developed property to the general Market. This includes purchase from the Market and sales or purchases negotiated with other players.	Requests to buy or sell are input by Developer. If purchase is from Market, a bid price is input; same for negotiated sales. If sale to General Market, no price is input, but is calculated by SELL.
Results of rezoning requests for Developer-owned land.	Input by Politician.
Requests to develop land and results, including costs.	Requests are input by Developer, in units or acres to be developed. Costs are calculated by computer on basis of number of acres or units.
Offer of developed land for sale to market and results, including sales price.	Property offerings are input by Developer; actual sales and final sales price are calculated by SELL.
Table of land holdings, by analysis area, according to developed land use or vacant zoning category. (For format of all property distribution tables, see below)	Calculated on basis of all land transactions in cycle added to or subtracted from previous holdings.
Financial statement, including starting cash position, money expended and income earned, net worth and change in net worth, taxes and loan payments owed next cycle, borrowing limit.	Calculated on basis of all the Developer's activities.

COMPUTER INPUT FROM PLAYERS

By the end of each gaming period, each APEX player (or team) will have turned in several decision forms to the gaming operator, representing the decisions made during that cycle. These player decisions then become input to the computer, and input to some of the specific models and routines in the computer simulations.

On the following pages are listed the specific kinds of decisions which the various players may make, the computer model or routine which they will affect most directly, and the interactions with other players. There is a separate list for each role, such as "Computer Input from Politicians," "Computer Input from Managers," and so on. Of course, the players do not feed this information directly into the computer, since the gaming operators must "translate" the player decision forms into punchcards or other forms which can be "understood" by the computer.

As for the computer output, most of the computer input from players occurs on the regular, annual cycle. However, the various types of decisions may have somewhat different timing. The issue decisions are expected to be completed and forms turned in early in the cycle. Land buying and selling can occur at any time during the gaming period. And other decision forms can be turned in at any time, but the different players or teams will complete them with varying speeds.

The APCO, Industrialists, and Managers will also be operating on the quarterly AIR cycle, making decisions which may get input to the computer four different times during the gaming period. This does not mean that they will automatically have such decisions to make, since that will depend upon the output of the AIR model, reporting the conditions of air contamination.

COMPUTER INPUT FROM POLITICIANS

Computer Program		Decision		Players with Allied Interests
Influences VOTE and ELECT	←	Select Desired Alternative For Issues Arising in Newspaper	------	All other Players
SELL		Buy or Sell Public Land	--------- ---------	Manager Developer
File update	←	Rezone Land	←—— —— ——	Manager Developer Industrialist
Affects AIR	←	Pass Air Pollution Control Ordinances (County only)	←	Air Pollution Control Officer
		Revenues		
File update	←	Normal Operating Millage		
VOTE	←	Raise local Millage Limit (if appropriate; for normal operating millage)		
VOTE	←	Seek Special Millage		
		Expenditures		
Accounts	←	Operating Budget	---------------- ←——	Manager (County Health Director)
Accounts, SPREAD	←	Capital Budget	←——	Manager
VOTE	←	Bond Issues Sought		

Dashed line (-----) indicates consultation may be appropriate

Solid line (_____) indicates decision is formally linked to another player's action; arrow shows direction of decision flow.

COMPUTER INPUT FROM MANAGERS

Annual

Computer Program	Decision	Players with Allied Interests
Affects VOTE ←	Select Desired Alternative For Issues Arising in Newspaper	- - - All Other Players
	Rezoning Requests	→ Politician ← Developer ← Industrialist
Accounts ←	Prepare Capital Program	→ Politician
AIR ←	County Only Health Director's Operating Budget	→ Politician ← Air Pollution Control Officer
	Quarterly	
AIR ←	Incinerator Operation	← APCO

COMPUTER INPUT FROM AIR POLLUTION CONTROL OFFICER

Computer Program	Decision	Players with Allied Interests
	Annual	
Affects VOTE ←	Select Desired Alternatives Native from Issues Arising in Newspaper	----------- All Other Players
AIR ←	Operating Expenditures Monitoring Investigations Public Information and Education Legal Actions Miscellaneous	---------------- Health Director (Manager)
Accounts ←	Funds Sought From County	→ Health Director (Manager)
	Quarterly	
AIR →	Order Investigations	
AIR ←	Issue Orders	→ Industrialist
	Request Additional Authority	→ Politician

COMPUTER INPUT FROM INDUSTRIALISTS

Computer Program	Decision	Players with Allied Interests
	Annual	
Affects VOTE ←	Select Desired Alternative For Issues Arising in Newspaper	- - - All other Players
Accounts ←	Pay Taxes	
Accounts ←	Make Loan Payments	
	Determine Production	
	Plant Expansion	
SELL ←	Buy Land	- - - Politicians - - - Developers - - - Other Industrialists
	Seek Rezoning	- - - Politician → Manager
Accounts, AIR and GROW ←	Overall Plant and Equipment Expenditures	
AIR ←	Air Pollution Abatement	← Air Pollution Control Officer
Accounts ←	Determine Promotional Expenses	
Accounts ←	Request New Loans	- - - Developers - - - Other Industrialists
Stock Market ←	Offer Stocks and Bonds for Sale	
Accounts ←	Declare Dividends	
	Quarterly	
AIR ←	Abate Air Pollution	← Air Pollution Control Officer

COMPUTER INPUT FROM DEVELOPERS

Computer Program	Decision	Players with Allied Interests
Affects VOTE ←	Select Desired Alternative For Issues Arising in Newspaper	------------ All other Players
Accounts ←	Make Loan Payments	
Accounts ←	Request New Loans	
Accounts ←	Pay Taxes	
GROW ←	Invest in an Exofirm	------------ Politician
SELL ←	Buy or Sell Property	------------ Politician ------------ Other Developers ------------ Industrialists
	Seek Rezoning	------------ Politician → Manager
SELL ←	Request Development of Land	
SELL ←	Offer Developed Land for Sale to Market	
ELECT ←	Make Campaign Contributions	------------ Politician
Accounts ←	Make or Seek Cash Transfers	------------ Politician ------------ Other Developers ------------ Industrialists

COMPUTER SIMULATIONS

APEX includes five major models which simulate some primary processes of development in the simulated metropolitan area. A series of smaller routines are more directly related to gamed decision roles, for calculating accounts and preparing other parts of output to be used by players

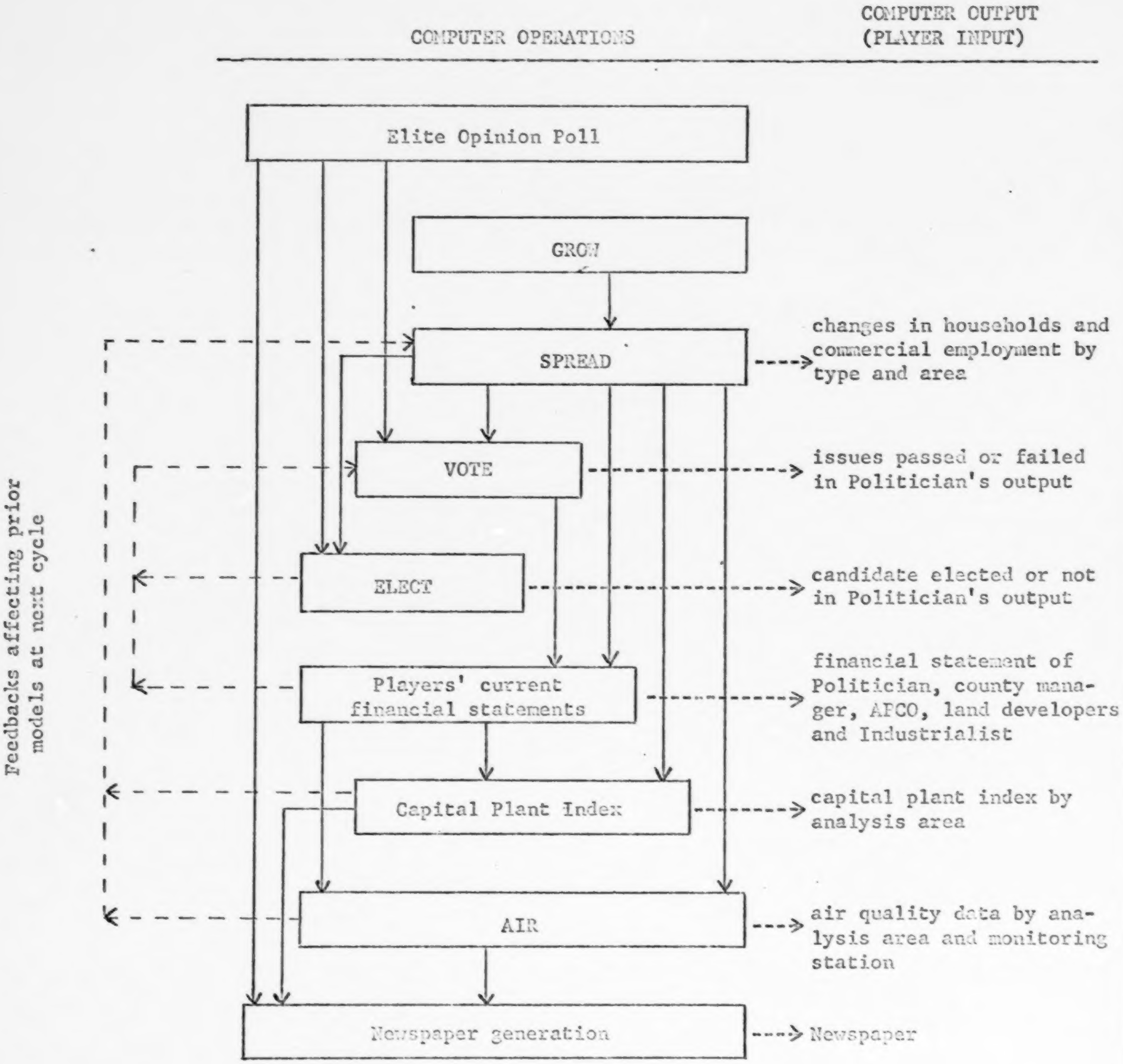
The major models and routines are closely linked together in the interconnected APEX computer program. Shown in Figure 27 are GROW, SPREAD, VOTE, ELECT, AIR and the routines of the Elite Opinion Poll, (POLL), the Financial Statements Calculations, the Capital Plant Index Calculations, and Newspaper Generation. Each model depends for its inputs on calculations in other models in the same or previous cycles and on a common base of data for the metropolitan area, (except GROW which provides an exogenous input to the whole program).

SPREAD, for example, receives projected exogenous employment by type and analysis area from GROW. It also receives the quantity and quality of public facilities, (Capital Plant Indices), as a result of the decisions of Politicians in the previous cycle. Capital Plant Indices (ratio between net worth of public facilities in an analysis area and the population equivalent of that area) in their turn depend on SPREAD for the calculation of population equivalent. Other inputs to SPREAD are air contamination levels from AIR and zonong changes by Politicians (read in every cycle).

Similary linkages can be shown for every part of the APEX computer simulation system. The sequence in which the model programs are executed has to be programmed so that all data necessary for any one model has been calculated in some preceding phase of the program. The order in which the models and important routines are executed in APEX is shown in Figure 27 , together with the main linkages of the system.

Figure 27

SEQUENCE AND LINKAGES FOR
MAJOR COMPUTER SIMULATIONS


COMPUTER OPERATIONS
COMPUTER OUTPUT (PLAYER INPUT)
Elite Opinion Poll
GROW
SPREAD
changes in households and commercial employment by type and area
VOTE
issues passed or failed in Politician's output
ELECT
candidate elected or not in Politician's output
Players' current financial statements
financial statement of Politician, county manager, APCO, land developers and Industrialist
Capital Plant Index
capital plant index by analysis area
AIR
air quality data by analysis area and monitoring station
Newspaper generation
Newspaper
Feedbacks affecting prior models at next cycle

Linkages within the same cycle are shown in solid lines, while the feedbacks to prior models at the next cycle are shown in dashed lines. Several models and routines result in data which is processed in the following cycle. For example, the Capital Plant Indices and AIR data influence SPREAD by such feedbacks, and the Politicians' Financial Statements influence VOTE and ELECT in the next cycle.

GROW - Exogenous Growth Model

The growth of employment and population is basic to most other changes in the metropolitan area, so that it is calculated first. Exogenous employment represents employment in firms which produce goods and services for a market located primarily outside the APEX metropolitan area, and this is broken down into white collar (bureaucratic) and blue collar (industrial) exogenous employment. Endogenous employment depends on growth of population and exogenous employees, so it is assumed that all area growth results from changes in exogenous employment.

A given increase in exogenous employment initiates a sequence of changes in population and endogenous employment, with each round of effects decreasing until those effects are negligible. Thus, an initial increase in exogenous employment causes demand for services to the exogenous industry, and these both lead to increase in households. New households create more demand for services, which increases endogenous employment, which increases the number of households, and so on.

GROW provides the basic exogenous growth which starts this chain of effects. For this model a constant unemployment rate and no commuting to or from anywhere outside the APEX metropolitan area are assumed, so that there is full and direct impact of changes in local employment on households in the area.

When the first APEX cycle begins, the exogenous employment by type and analysis area is assumed to be known. The numbers of exogenous employees are updated every cycle by projected growth based on the following:

1. Growth of the gamed industries which depends on the managerial operations of gamed Industrialists and on the assumed national economic growth rate (representing their exogenous markets).
2. A 2.5% annual growth rate for the state government (large office-operations firm).
3. A 9.0% annual growth rate for Michigan State University (a large research-educational complex) during the first five cycles and a 4.0% annual growth rate in the remaining cycles.
4. Three different growth rates for all other simulated industries, representing the growth characteristics of different types of industry in the metropolitan area.
5. The total employment of any exogenous industries (exofirms) entering the area during any cycle.

These calculations result in exogenous employment by type and analysis area at the end of each cycle. This then becomes the base for the calculation of total employment and total households during that cycle, which is performed by SPREAD.

SPREAD - Endogenous Growth and Distribution Model

SPREAD has the following major functions:

1. Calculation of changes in total number of endogenous employees and in total number of households.

2. Calculation of changes in the geographical distribution of households (by type) and of commercial employment (by type) and of the corresponding land uses.

These changes are calculated on the basis of changes in level and distribution of exogenous employment (from GROW) and the current number and distribution of endogenous employment and households. SPREAD is a version of T.O.M.M. (Time Oriented Metropolitan Model) which was designed by Dr. John P. Crecine. SPREAD provides approximations of endogenous growth and distribution on which will appear realistic to APEX participants.

SPREAD has been built on the following assumptions:

a. SPREAD is primarily a gravity model, relating the distribution of households primarily to the distribution of employment. Some social and physical characteristics of analysis areas are also introduced to distribute households by type within each analysis area. (The parameters in the model have been estimated by using regression techniques.)

b. SPREAD assumes that a balanced redistribution of population and commercial employment can be achieved within the relatively short period of one year, initiated by a change in level and distribution of exogenous employment. Subsequent changes in endogenous employment and population and their spatial distribution are handled simultaneously by a series of iteractions that ends when a (previously defined) situation of balance is achieved. This process of growth by iteractions leads to the several rounds of effects referred to above.

c. The smallest spatial unit in the model is the analysis area, with twenty-nine analysis areas for the entire metropolitan area of APEX.

d. For every analysis area a stable number of households and a stable amount of residential and commercial land use is set. The underlying assumption is that within one cycle the mobility of households and commercial employment will never lead to a loss of inhabitants or commercial employees or related land uses in any analysis area below these set levels.

In every iteration of SPREAD, the following calculations are carried out. The residential loop begins with the calculation for every analysis area of the amount of available land for residential purposes, which consists of the vacant land zoned residential and the non-stable part of the residential land already in use. The amount of available land for commercial activities is also calculated. The second step involves the calculation of the total number of households based on the projected level of exogenous employment and a constant ratio between the number of households and jobs. This total number of households is then distributed over the twenty-nine analysis areas, using as criteria the employment potentials and the amounts of available residential land in each analysis area. The employment potential of an analysis area is a factor which aggregates the weighted distances to employment opportunities in all other analysis areas. The number of households allocated to every analysis area is proportional to the sum of employment potential and available residential land in the area. The new household totals for each analysis area are then compared with the calculated stable number of households and with the maximum residential density allowed by existing zoning regulations. To eliminate possible deficiencies or surpluses, a redistribution is executed, with all other analysis areas contributing to this process of redistribution in proportion to their calculated total number of households.

After the total number of households by analysis area is known, this total is distributed within each analysis area among the five household types. The criteria used include the current household composition (assuming that households prefer to locate in areas already occupied by a substantial number of households of the same or higher types), the quality and quantity of school and local public facilities (streets, sewers, parks, water), the air characteristics (contamination levels), and the employment potential (which includes in this case separate indices for total endogenous, exogenous, industrial, and exogenous bureaucratic employment). Parameters have been estimated to represent the different evaluation of these criteria by different household types. This completes the residential loop.

The commercial employment loop starts with the calculation of a new commercial employment total (by type) based on the total number of households (by type) which is derived from the residential loop. A parameter is used here to represent the generation of different demands for services by different household types. Commercial employment totals (by type) are then distributed to analysis areas. This process is determined by the current distribution of households (by type) and (to a lesser degree) by the distribution of total, exogenous industrial and exogenous bureaucratic employment. Parameters have been estimated to represent the different importance of household types and employment types for the generation of commercial services.

SPREAD then calculates the impacts on land uses (by analysis area) of the generated spatial distribution of households (by type) and endogenous employment (by type). By comparing new totals with previous totals, changes in number of households and endogenous employees (by type) are calculated for each analysis area. Changes in residential and commercial land use are also calculated. Some of these changes are then compared with previously defined tolerance limits, which define when the system is considered to be in balance. If changes are larger than tolerance limits, a new iteration will start with new current totals for the amount of available residential and commercial land by analysis area, commercial employment by analysis area, and number of households by type and analysis area (this last variable is only used in the residential loop).

VOTE - Voters' Response Model

VOTE simulates the response of the electorate to bond and special millage issues proposed by Central City and County Politicians. School and non-school issues are differentiated, as are basic and nonbasic types. The input of VOTE consists of two sets of data:

1. Data concerning the jurisdiction where the election is held (Central City, County) include: maximum legal tax rate, current tax rate, maximum legal bond debt, current bond debt, population by household types, total assessed value, unemployment rate, and returns of the Elite Opinion Poll in that jurisdiction.
2. Information concerning the issue proposed includes: type and value of the bond or special millage, number of years to pay, campaign contributions, consensus of other players in jurisdiction on whether or not to support the given issue.

VOTE calculates the number of eligible voters who will vote on the issue and the number of "yes" and "no" votes. During this calculation parameters are used which have been estimated by studying the reactions of voters on different types of issues in the Lansing area. The returns from VOTE appear in the Politicians' output and are fed into the accounting system calculating the Politicians' budget.

ELECT - Candidates Election Model

ELECT pits the gamed Politicians against opponents whose actions are simulated in the computer. The primary determinant of the election outcome is the success of the Politician in stressing, through dollar expenditures, his stands on issues during his campaign, relative to the success of his simulated opponent. The final outcome also reflects the Politicians' performance as an incumbent, in terms of his fiscal and political policies.

The Politician wages his campaign by making expenditures (stressing) on certain issues which have come up during his term of office. His simulated opponent has a similar set of stresses. That opponent is identified for the gamed Politician as representing some position on the political continum, ranging from ultra-conservative to very liberal. The Politician receives an estimate of his standing, similar to a Gallup or Harris poll, after one round of stresses on issues, midway in his campaign. With this estimate to guide him, the Politician concludes his campaign by allocating his expenditures (stresses) as he deems appropriate to further his chances of winning the election. These stresses are processed and the outcome of the election is determined on the basis of comparative success of candidate and opponent in pleasing their constituents and the measures of candidate performance during his term.

The first subroutine in ELECT computes the amount of money contributed to the party by the Politician on the basis of his success in pleasing party influentials. This success is measured by considering the proportion of times the Politician agreed with the majority in the Elite Opinion Poll. This figure is added to the money accrued by the Politician for exerting his influence on behalf of gamed players (his bribes). A second routine computes the stresses applied by his opponent to each issue which arose during the course of the last two gaming cycles. These stresses are predetermined for each type of opponent for each issue and stored. The third routine allows the Politician to enter his dollar stresses for each issue and converts these dollar values into appropriate stress figures. The fourth routine then computes the attitude of each household type and pressure group toward the candidate and his simulated opponent on the basis of stands taken by them on each issue of the last two cycles. The main routine then considers the household attitudes, relative power of each household type, pressure group attitudes, stresses of each election participant, and the pre-set importance of each issue to determine a turnout of voters in support of each candidate. This turnout is then modified according to the performance of the incumbent with respect to taxation policies, budget allocations, and capital plant program.

AIR - Air Contamination Model

AIR is being designed to generate quarterly reports to the APCO on the level of air contamination in various parts of the metropolitan area. It will combine information about critical contaminants and weather to produce realistic air characteristics with appropriate seasonal and climatic variations. AIR is not intended to be predictive, but rather to present data to the APCO which provides a realistic approximation of the data he would get from monitoring stations and spot inspections.

Reports to the APCO will include measures of seven contaminants: dust, particulate matter, nitrogen oxides, sulfur dioxide, carbon monoxide, hydrocarbon, and ozone (which results from a chemical reaction involving other contaminants). Other pollutants might be included, but these should provide sufficient diversity without getting too complex. Measures of contamination level for each contaminant will be generated daily, although only reported quarterly. The primary measure will be the maximum level of contaminant in the air on each day for each analysis district. (It may prove possible to store typical patterns for variations over the course of a single day, which could be fitted to the maximum level generated for an analysis area for some given day, then reported out as the hourly variation for that day.)

AIR will generate daily winds, temperature, humidity, sunlight, and height of inversion layer, using stochastic sampling techniques. Daily temperature readings will be simulated by an autocorrelated, seasonally-influenced random sequence. Typical wind patterns will be preset, with one selected for each day by stochastic sampling (possibly also an autocorrelated random sequence). Humidity and sunlight (cloud cover) may be handled in a similar fashion. Frequency of occurence of stagnation periods due to mass temperature inversions will probably be regulated by some stochastic sampling technique, with the possibility of operator option to determine when these occur. All of these weather variables will be used to modify the parameters of the distributions used to generate contaminants from various types of contamination sources.

Contamination levels for each contaminant will result from residual, uniform, line, and point sources. Residual contamination is that included in an air mass as it moves over the metropolitan area from outside. Uniform sources are those which are spread fairly uniformly throughout the metropolitan area (such as residential and commercial heating). Line sources are primarily automobile exhaust contaminants which are generated along expressways and major traffic arteries. Point sources are those which are located at specific points within the metropolitan area, such as industrial plants, incinerators, and so on.

Residual contamination will be assumed as part of the entering air mass. They will be preset for each run to control absolute contaminant levels. Uniform contamination will be based on the land uses and households in various sections of the community, varying over time as those change in APEX. Line sources will probably be based on assumptions about household car ownership and trip generation potential as measured by the employment potential of each analysis area, with special attention to major expressways and traffic arteries. Point source contamination will be generated using some form of Gaussian diffusion model. A list of all potential industries and other point sources will be stored with their contaminant emission characteristics, so that contamination rates for those in operation at any given time can be calculated.

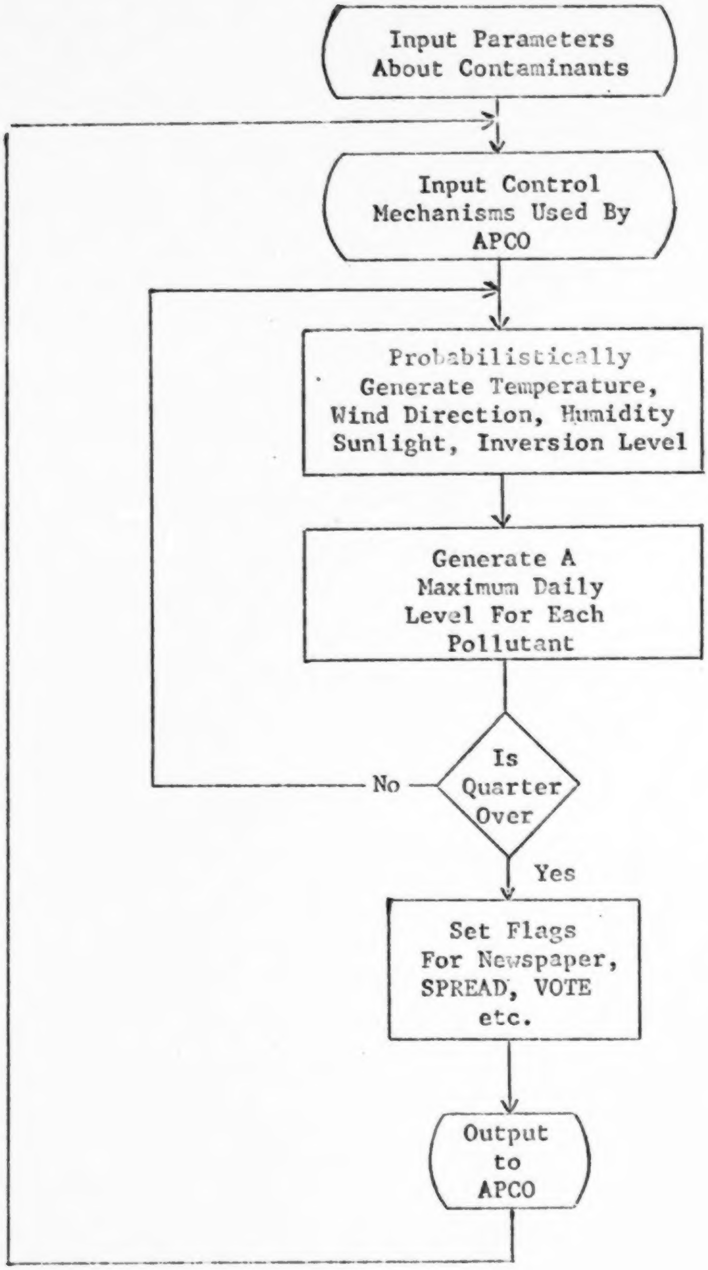
Gamed industries will be developed so that their contamination rates will respond to Industrialists' decisions on production level, types of fuel used, air pollution control equipment installed, and so on. A set of possible actions by the APCO and the gamed Industrialists will be stored, so that they can be called at the beginning of each quarterly AIR model cycle. The APCO will also be able to get specific information on point sources being operated by gamed Industrialists, which he can use as the basis for abatement orders, or, if necessary, in hearings and court cases. It may also be possible to permit the APCO to request information about the immediate effects of his orders on the simulated industries or on the general uniform or line sources.

The effects of new or varied line and point sources can be approximated by modifying the parameters of distributions for specific contaminants from specific sources in specific analysis areas. By varying the mean or skewness of the appropriate distributions, deviations from the typical patterns can be generated randomly or imposed by actions of gamed players. These contaminant emissions will affect levels of contamination in all downwind analysis areas when the combined effects of residual, uniform, line, and point sources are brought together with weather variables for each analysis area to arrive at the measure of daily maximum contaminant level for each contaminant. These contaminant levels will be generated for a monitoring station in each of the twenty-nine analysis areas, but information will only be reported out to the APCO for those areas in which stations are installed. Perhaps the frequency of occurrence of these reports can be increased in times of crisis, when contaminant levels approach or cross specific levels defining legal air pollution.

Following this approach it will be possible to have daily contaminant levels trigger "panic reports" through the newspaper, altering all players to the situation, as well as permitting this kind of reporting to be handled by the APCO, if that is desired. Generating weather and contamination data offers the potential for other detailed uses, including those leading to MAPCORE exercises, but it will give an AIR model that takes more time to run at each quarterly cycle, which will always constrain the amount of details that can be included.

The basic weather variables can be varied for different APEX runs or rounds, making it possible to approximate quite different basic climatic

Figure 28



Input Parameters About Contaminants
Input Control Mechanisms Used By APCO
Probabilistically Generate Temperature, Wind Direction, Humidity Sunlight, Inversion Level
Generate A Maximum Daily Level For Each Pollutant
Is Quarter Over
No
Yes
Set Flags For Newspaper, SPREAD, VOTE etc.
Output to APCO

and meteorological situations. Possibly this can also be considered to include major topographical differences. In any case, the AIR model will be developed so that APEX can be run on the assumption that it is situated in widely-differing climates and weather situations.

MAJOR ROUTINES

Besides the major models there will be many computer routines in APEX that perform simpler tasks, such as the calculation of accounts, indices, and land values. Some of these routines are closely related to the preparation of output for gamed roles, while others provide the information used in many other parts of the system. The following summary of routines is based on this distinction.

Routines for General Application

This category of routines is sused to update many quantitative characteristics of the simulated APEX environment. Changes are initiated by the outputs of some models (such as SPREAD) or directly by players' decisions. The output of each of these subroutines is used in several other routines or models. Most of these are already operational.

A1. The Capital Plant Index Routine first calculates the population equivalent for each analysis area, based on the new population and employment totals calculated by SPREAD. The next step is the calculation of the depreciation of the value of current capital plant investments in the different categories (streets, sewers, water, parks, schools, and miscellaneous) by analysis area. The new capital plant investments are added to these totals giving new total values for each analysis area. The totals are finally established as a ratio to the population equivalent to obtain the new capital plant indices. These indices appear in the

Politicians' and Managers' outputs. They also are inputs for the land value routine and next cycle's SPREAD. For the generation of headlines in the newspaper, a capital plant adequacy check is executed: the present value of the capital plant index is checked against a standard of adequacy value to determine the current standing of the capital plant indices of any analysis area. If the current standing is below the standard, headlines will appear in the newspaper.

A2. The Land Use Value Routine updates the land values of improved and vacant land in the various land use and zoning categories each cycle for each analysis area. An initial dollar value is set for every category of improved and vacant land in each analysis area. This value is related to an index that is updated each cycle for changes in capital plant indices, air quality, and demand for land (from SPREAD) compared with the total land available in the particular land use category. For the different land use types different additional criteria may be included. The indices are subsequently converted into actual dollar values by multiplying them by the initial dollar values. The calculated values of vacant land set the prices for all land transactions in APEX. The calculated values for both vacant and improved land are inputs to the Tax Generating Routine.

A3. The Price Updating Routine updates prices for developed land by land use category, development cost level, and analysis area. A similar type of index is used as in the land value routine, but broken down for the different development cost levels. The calculated prices apply to all sales and purchases of developed land in APEX.

A4. The Rezoning and Land Use Updating Routine first handles the Politicians' rezoning decisions and purchases of developed land to update the distribution of the five zoning categories over each analysis area. The amount of improved land in each land use category by analysis area is then calculated (which depends on inputs from SPREAD).

A5. The Tax Generating Routine generates the tax revenues by jurisdiction for both the municipality and the school board. It begins to update the millage levels (Politicians' and school boards' decisions) and checks for discrepancies of millage levels with the state millage limits. For the calculation of the tax base the vacant and improved land values (from the Land Values Routine) are multiplied by the amount of land in the corresponding land use or zoning categories (from the Rezoning and Land Use Updating Routine) to produce the total property value by analysis area. Then the total property value of all analysis areas in the jurisdiction is calculated and this total is multiplied by the assessment ratio to produce the total assessed value for the jurisdiction. The tax revenues by jurisdiction are computed from this tax base and the millage levied in each jurisdiction (minus a certain proportion for delinquency).

A6. The Exofirm Entering Routine checks of the conditions for establishment of an exofirm in the metropolitan area have been met and decides the ultimate location. These conditions include: sufficient land in the appropriate zoning category and sufficient expenditures on public facilities by the municipality. If all conditions have been met in more than one of the analysis areas where the new exofirm announced it desires to locate, the firm will locate in the area of its preference, which is the order stated in the newspaper announcement. (This is output to GROW.)

A7. The Land Sales and Purchasing Account keeps running accounts for landholdings of players by zoning category and analysis area updated every cycle. This routine will handle the land transactions of Developers, Industrialists, and Politicians.

A8. The Traffic Accessibility Updating Routine updates the traffic accessibility factors each cycle for each analysis area. This is done on the basis of changes in the street indices of all analysis areas (from Capital Plant Index Routine) and the simulated allocation of federal funds for highway construction. The results are an important input to SPREAD.

A9. The Non-White Population Percentage and Local Unemployment Determiners are two small routines that update the non-white population and unemployment percentages by an analysis area each cycle.

A10. The Players' Standing Output Set prepares a separate set of output for each player, combining the various information (calculated by models and other routines) relevant to the particular player.

A11. The Output Control Routine provides format and structure for certain lead-in information for the output each cycle, such as heading, cycle number, and date.

A12. The Newspaper Generator generates a newspaper describing the variety of community conditions and information concerning activities or actions that are relevant to the players. It includes the generation of random headlines as well as those of explicit importance to the gaming.

Specific Role-Related Routines

The following routines are specifically related to the various gamed decision roles in APEX. Politicians' and Developers' routines are operational, while APCO's and Industrialists' routines have to be worked out in detail.

B1. The Politicians' Budget Routine successively calculates the three separate parts of the financial statements of the Central City and

County Politicians: operating budget, capital budget, and personal budget (used to finance the Politicians' campaigns for re-election).

B2. The Community Credit Rating Routine calculates each cycle the community credit rating for each jurisdiction, which influences the interest rate for new bonds. The credit rating influences the interest rate for new bonds. The credit rating is influenced by the loan and interest payments history of the jurisdiction.

B3. The APCO's Operating Budget Routine produces the detailed budget of the APCO, which is a line item of the County Politicians' operating budget.

B4. The Monitoring Stations and Regulations Listings carries an up-to-date list of all installed monitoring stations which will report AIR data to the APCO and all regulations imposed on Industrialists and others to abate air pollution.

B5. The Developers' Loan Evaluation Routine checks on the financial eligibility of any Developer requesting a loan, to determine whether or not it falls within the maximum limit set for him.

B6. The Developers' Taxes Owed Routine calculates the taxes owed each cycle, based on the value and location of landholdings of each Developer and the respective millages of the jurisdictions in which that land is located.

B7. The Developers' Building Sales and Purchases Accounting Routine keeps running accounts of the buildings and improvements held by the Developers by analysis/ area and land use category.

B8. The Developers' Exofirm Investments Routine lists the investments in exofirms for each Developer and calculates returns on that investment.

B9. The Developers' Budget Routine calculates the financial statements for each Developer.

B10. The Industrialists' New Plant Investments Check checks for new investments in plants to see that sufficient land is available. If not, the new plant investments will be cut proportionally.

B11. The Industrialists' Depreciable Assets Updating Routine calculates the value of depreciable assets based on yearly depreciation and new investments.

B12. The Industrialists' Loan and Bond Evaluation Routine checks the financial eligibility of any Industrialist for a loan or bond issue by testing whether or not it falls within the maximum limits set for him (among others a minimum ratio between capital and loans/bonds will be maintained).

B13. The Industrialists' Stock Market Simulation Routine calculates the percentage of new shares offered by the Industrialist to the market that will be sold at the given price. This percentage depends on the existing ratio between total value and capital, and dividends and growth in previous years.

B14. The Industrialists' Sales Routine calculates the yearly amounts (number of units) and value of products sold. This depends on production level, amount of selling costs and an external factor which will be different for the various types of industries (for exofirms it might be the national unemployment rate).

The three financial statements for the Industrialists are calculated by the following routines:

B15. The Industrialists' Total Revenues and Expenditures Routine

B16. The Industrialists' Gross Profit Division Routine

B17. The Industrialists' Balance Sheet Calculation Routine

This summary of the Industrialists' routines is completed by some small subroutines calculating the levels of production, employment, and of different air contaminants generated.

Routines For Simulated Roles

APEX will have some sectors that are completely or partly simulated These are:

a. The simulated school boards (all six simulated).

b. The simulated municipalities (five are simulated)

c. The simulated industries (only seven are gamed, at a maximum)

Special submodels or routines are necessary to simulate these activities. None of these has yet been worked out in detail.

C1. The Submodel for Simulated School Boards simulates the activities of the six school boards in APEX. Results of these simulated activities will be a part of the Politicians' output from the computer (the Central City Politicians and the five County Politicians who represent the five simulated municipalities). A simple model is necessary to simulate educators' decisions on teachers' salaries, other operating expenditures, capital improvement programs, and requests for special millages and/or bonds. The amount and allocation of expenditures in the budget prepared by the simulated school board depends on the ratio in each analysis area between some standards for quality of school facilities and services and the current quality of those facilities and services as calculated by some indices for each analysis area. For high school facilities and services a combination of analysis areas (as the service area of the high school) will be the base for calculating these indices. The indices are the investment in school facilities per pupil and the pupil-teacher ratio.

The model will try each cycle to eliminate the difference between the standards and current indices. The budgeted expenditures are directed to this goal. If tax and other revenues are lower than the budgeted expenditures, a bond issue or special millage will be proposed. These will be processed by VOTE as for gamed bonds and millages. If a proposal fails, the budget will be cut proportionately and the current indices will be below standards as a consequence.

C2. The Submodel For Simulated Jurisdictions will deal with the five municipalities outside the Central City which are simulated. Results of these simulated activities will be a part of the output for the five County Politicians representing those areas of the County. The operational budget is largely dependent on population growth (from SPREAD). The capital improvement program for the municipalities is decided by the County Politicians. The tax revenue of each municipality (from the Tax Generating Routine) is used primarily for the operational budget. For possible deficits, a special millage will be proposed which is processed by VOTE to simulate a referendum in the appropriate jurisdiction. Possible surpluses will be used for financing the capital improvement program. For the remaining amount needed for capital improvements, a bond issue will be proposed by the County Politicians, processed by VOTE to simulate a referendum throughout the County. When special millages or bond issues fail to gain approval, the proposed expenditures of the operating and capital budgets will be cut proportionally.

C3. The Submodel For Simulated Industries generates a list each cycle of the characteristics of simulated industries that will be printed on request of the APCO. These characteristics include: production and employment levels, fuels used, and the rates of air contaminant emission. To calculate changes in production and employment level, three growth rates will be established. Industries will be typed by air contamination characteristics, each type representing a different ratio between production level and amount and composition of contaminant emission. These air contamination characteristics can be changed by oxogenous inputs, representing the APCO's orders to install air pollution control equipment, to change fuels, or to otherwise abate contaminant emissions.

FUTURE APEX DEVELOPMENT STAGES

This report has described the first stage in the development of the APEX gaming simulation for hte Air Pollution Control Institute training program. The basic concepts presented here are intended as the specifications upon which the further stages will be based. It is critical that all parties concerned with its future development and use review these concepts carefully and make comments and suggestions before the next stages proceed.

The remaining stages involve the development of detailed flow charts, the conversion of those flow charts into operational computer programs and gamed decision roles, the preparation of gaming materials, the blending of gaming and computer parts together into an operational unit, its testing through preliminary and demonstration runs, and training of operational staff to put APEX into routine use as an integral part of the APCI program.

Flow charting is the necessary base for both the detailed programming of computer simulations and the detailed working out of the gamed decision role, interactions, and gaming materials. Although substantial portions of both are operational in METRO, major alterations will be required in existing parts. Major additions, like the AIR model and routines for the APCO, Industrialists, county roles, simulated muncipalities and school boards, have not been worked out at the detailed flow chating level.

Computer programming, working from the detailed flow charts, will probably be the most critical path for future APEX development. Programming of alterations and additions will be accomplished in FORTRAN for operational use on the IBM 1130-2B (which is available at both the Environmental Simulation Laboratory and the Air Pollution Control Institute). Programming can start as soon as flow charts are available, and programming and debugging will undoubtedly continue throughout the remainder of the APEX stages.

Major focus on gamed decision roles, gaming materials, and gaming staging is especially critical for APEX. If the completed gaming simulation is to become an integral part of the APCI training program, special priority must be given to working these parts out. Special efforts must be made to work closely with the APCI staff to insure that their knowledge about the training program and their ideas about how APEX can best be developed as a training tool are built upon. The prospect of routine, regular use in the training program emphasizes the need to concentrate major efforts on the gaming parts of APEX. Although APEX development does not include specific design of MAPCORE exercises, the potentials for linking into existing and future detailed, programmed sessions between gaming periods must be considered throughout APEX development.

The final stage is that of getting APEX operational for the APCI. This will call for a number of preliminary runs at the Environmental Simulation Laboratory, followed by demonstration runs to make APEX operational at the University of Southern California. The latter runs should also serve as initial training experience for the staff which will operate APEX for the APCI. This will meet the major objectives of the APEX efforts, although there will undoubtedly be continuing development and refinement as this gaming simulation is worked into the training program.

This final stage will also include a brief written report, including recommendations for future refinements. Some form of documentation of the APEX computer simulation program will also be completed, probably in detailed flow chart form.

GLOSSARY

ANALYSIS AREA (A.A.)

Analysis areas are used as the primary areal reference units for the data and issues throughout the game. Each of the municipal jurisdictions, simulated cities and Central City, is divided into a number of analysis areas, each of which is the approximate size of several census tracts. The analysis areas included in the five municipalities are as follows:

Central City: Ward 1 -- AA 1 through AA 4
Ward 2 -- AA 5 through AA 8
Ward 3 -- AA 9 through AA 13
Simulated City A -- AA 14 through AA 16
Simulated City B -- AA 17 through AA 19
Simulated City C -- AA 20 through AA 22
Simulated City D -- AA 23 through AA 25
Simulated City E -- AA 26 through AA 29

See APEX Analysis Area map

ASSESSED VALUE

Assessed value is the base on which millage is levied to generate revenue for political jurisdictions and school districts. Jurisdictions are required by law to maintain an assessed value of 50% of market value for property in their jurisdiction. (E.g., if a residential property is valued on the market at $20,000, its assessed value is $10,000.) This 50% figure is known as the assessment factor.

BONDING

Bonding is the process of incurring debt to finance some government facilities and services such as capital improvement projects or special education programs.

Before Politicians or Educators may float bonds to finance projects, voters must approve this action in a referendum. There is a maximum limit on the bonded indebtedness that a jusisdiction or school board may incur. This limit is state imposed. The amount of additional bonded indebtedness that can be sought is indicated in players output as "$ Limit on Next Bond Sought." (See"Debt Retirement" for the process of financing bonds.)

CAPITAL PLANT INDEX (C.P.I.)

The capital plant index is a ratio of the present dollar value of capital facilities (sewers, water lines, streets, parks and miscellaneous public holdings) to population equivalents. (See "Population Equilavent") This is considered as an indication of the relative level of adequacy of these facilities.

Present dollar value is calculated each cycle on the basis of depreciated value of existing facilities plus new facilities. (Facilities depreciate at about 5% of original value per year.)

DEBT RETIREMENT (Debt Service)

Debt retirement, or debt service, is a term used to describe the process of paying off long-term bonds. Debt retirement is a budget category of the Politician and Educator which includes expenditures for both principal and interest on bonds. Financing of these expenditures may be with either normal operating or a special voted millage.

DEMOLITION COSTS (Clearance Costs)

Demolition cost is a charge of 5% of the value of developed property that is assessed to the player when he rezones land or purchases developed land from the market (in both cases the land becomes vacant automatically.)

DENSITY

In residential areas, density is the term used to express the number of dwelling units per acre of land. In APEX a different density is associated with each of the four residential land use types with the lowest density found in land use category 1 and the highest in category 4.

The densities of these categories also vary from one analysis area to another. The central areas of the cities have higher overall densities than outlying areas. Densities associated with the 4 residential use categories, by analysis area, are found in table .

DEVELOPMENT COSTS

A. Residential

In APEX there are various levels of cost associated with different qualities and sizes of housing which may be built by Developers.

Single Family

Three different development cost levels are applicable to APEX single-family housing units, ranging from the highest construction cost of $40,000 (designated as Level A) to the lowest cost housing, built at $9,000 per unit (designated as Level C).

Multiple Family

Units of three different cost levels, also designated from highest to lowest cost, A, B, C, are available for construction of multi-family housing in APEX. The highest cost per unit, for Type A, is $35,000 and the lowest, for type C, is $8,000.

DEVELOPMENT COSTS PER UNIT (IN $1000)

Cost Level	Land Use Types			
	R-1	R-2	M-1	M-2
A	40	40	35	35
B	20	20	15	15
C	9	9	8	8

B. Commercial

Two types of commercial land use are allowable in APEX. These relate to the local neighbor hood shopping facility and to the regionally-oriented commercial and service facilities. Both may be built only on zoning-category C land. Each is developed on a cost-per-acre basis, as follows:

	Commercial Development Type	
	LS	RS
Cost (in $1000/acre)	30	40

C. Industrial

Industrial development permitted Developers in APEX is on a per-acre basis, the cost being $50,000 per acre.

ELITE OPINION POLL (E.O.P.)

The Elite Opinion Poll is an advisory vote and enables the players to record their positions on all major policy issues raised in the APEX newspaper headlines. The poll is taken in each gamed jurisdiction every cycle and includes as participants all game players assigned to the respective jurisdiction. The results influence pressure group and general public attitudes on these issues. In addition, the results affect public officials' chances of re-election, as well as the probabilities of passage of general referenda and specific bond and special millage requests.

EXOFIRM (Exogenous Firm)

An exofirm is an industry or bureaucratic firm that depends primarily upon markets outside the local area for its growth and vitality. These firms are usually classified as exofirms on the basis of their being net importers of dollars and net exporters of products or services to these outside markets. Jobs created by exofirm growth spur additional growth of households and local market oriented jobs in the local area. (Exofirms are also often referred to as "BASIC" firms.)

In APEX exofirms locate in zoning category I. Periodically, the newspaper will note the opportunity for Developers to invest, in a speculative way, in the development of new exofirms with a variable probability of success attached to such investments. Occasionally these exofirms require special capital improvements to enable their development. This will be noted in the newspaper announcement of the firm's interest in locating in the area.

(See also "Zoning Categories")

HOUSEHOLD TYPES

The five household types used in APEX are characterizations of families who live in certain fairly homogeneous areas. These characterizations reflect life style, political importance and voting habits, general consumption behavior and preference for public goods.

Household Type I -- is upper middle class and upper class combined. Occupations of head of households are: professionals, technical workers, managers, officials and proprietors. One-half of the family income levels are in excess of $15,000, and the other half are in the $10,000-$15,000 range. (There is a substantial overlap of income levels for all status groupings, hence income is a weak indicator for characterizing households in census tracts.) Value of housing is in excess of $20,000, and if they rent, rentals are over $150 per month. Education of the head of the household is at least college graduate, often with post-graduate study.

Household Type II -- the typical middle-class household in which the head's occupation is clerical, sales, or kindred types. Income of the family is primarily in the $7,000-$10,000 range. Education of the head is some college or high school graduation. Housing value is primarily in the $15,000-$25,000 range, and gross rentals would be from $100 to $149 per month, though they may be somewhat lower.

Household Type III -- is characterized by a mixed membership of very low white collar workers, skilled craftsmen and foremen, though the latter two

ISSUE

Issue is used in APEX as a technical term in reference to a problem situation, presented to the players in a fixed form, which must be acted upon at the time it is presented. Not only is the form of the issue fixed by the written statement appearing in the newspaper, but the alternatives for action are also fixed. The alternatives, usually numbering between two and four, are printed out immediately below the issue statement. One issue must be selected (voted on in the opinion poll) by each player residing in the jurisdiction to which the issue applies.

(See "Elite Opinion Poll.")

JURISDICTION

Jurisdiction refers to one of the political units in APEX: the county, central city, or simulated municipality.

(See "Analysis Area")

LAND USE

Land use is used to refer to the types of structures built upon particular pieces of land. Each land use type is allowed only on lands of a particular zoning category.

(See "Zoning Category.")

MILLAGE

Millage is the tax rate, in mills, which is applied to assessed property value to generate property tax revenue. One mill is equal to a $1 charge on each $1000 of assessed value. There are two types of millage:

a. Operating millage is determined by local Politicians and is applied to standard operating costs of government and provision of basic services. Operating millage is limited in total amount by State and local law -- the local limit can never be higher than the limit set by the State.

predominate. (In the outlying areas, farmers are in this category.) Family income is primarily in the \$5,000-\$9,000 range. Head of household's education is typically high school graduation. Housing value is usually from \$12,000-\$20,000, and rental in the \$80 to \$125 per month range.

Household Type IV -- is composed of semi-skilled occupants, operatives and non-household service workers. Family income is in the lower portion of the \$4,000-\$7,000 range. Housing values are in the \$10,000-\$14,000 range, with gross rentals being \$70 to \$90. Education of the head of household is 8 to 11 years for the most part.

Household Type V -- is the lowest stratum of society, and heads of households are laborers or household service workers. Family income is less than \$5,000, and the value of housing is less than \$10,000, with rentals primarily \$50-\$70 per month.

IMPROVEMENT COSTS

Improvement costs are the fees to supply basic improvements such as connections to sewer and water trunklines, paved streets, curbs and gutters. Developers are required to pay improvement costs on land which they develop. This cost is a flat \$1000 per acre regardless of the type of development or zoning category.

This fee is automatically applied to the land on which the developer builds, so he must remember to leave enough uncommitted cash in his financial account to cover these costs.

Improvement costs can be calculated by the developer in two ways:

A. If starting with the desired number of units he wishes to build,

$$\text{Improvement costs} = \frac{\text{number of units}}{\text{density (from density table)}} \times \$1000$$

b. If starting with the number of acres to be developed, simply multiply acres by \$1000.

b. Special millage, which is not subject to State and local limits, can be used for specific purposes, such as debt retirement, special operating expenses. It must be voted on in a referendum.

Total millage is the sum of operating millage and any special millages which may be in effect during the year.

POPULATION EQUIVALENT

The use of the population equivalent is a way of converting (a) residents, and (b) employees and users of industries and commercial facilities, into a standard measure of the demand placed on such public facilities as sewers, streets, and water supply.

The population equivalent of an area (analysis area or jurisdiction) is computed, in terms of households, as follows:

P.E. = total number of households + 1.25 x (all employees of commerce and industry)

For the use of population equivalents in APEX, see "Capital Plant Index."

REFERENDUM

A referendum is a vote of the (simulated) population of a jurisdiction on some issue presented to the people by the Politician. Most usually referenda are called to approve (or reject) a bond issue or a request for special millage, although they may be called to approve some legislative matter, such as open housing.

REZONING APPLICATION FEE

The rezoning application fee is a charge of $100 which is assessed for each rezoning request submitted by a developer and which is included in the developer's tax statement for the next cycle. This fee is assessed whether or not the rezoning is granted.

SCHOOL ACCREDITATION RATING

Accreditation ratings are designed to represent various levels of school quality and capability. Such ratings are provided for the high schools in each ward. Three levels are possible with "1" denoting both North Central Association and University accreditation, "2" denoting just University accreditation, and "3" denoting no accreditation. In determining the respective ratings, four major factors are considered. These include the pupil/teacher ratio, the average teachers' salary, the operating expenditures/pupil ratio, and the school capital plant index. The voters are quite sensitive to downward shifts in accreditation ratings.

TAX RATE

See "Millage."

ZONING CATEGORY

Zoning categories, of which there are five, apply only to vacant land for APEX. Each zoning category may be developed into one or more types of land use:

Zoning Category	Land Use Type(s)
R -- Single-family residential	R-1 (low density) R-2 (medium density) RP (developed public)
M -- Multiple-family residential	M-1 (low density) M-2 (medium density)
C -- Commercial	CL (local shopping) CR (regional shopping, offices)
I -- Industrial	I-D (developed industry)
A -- Agricultural	A-F (active farming)